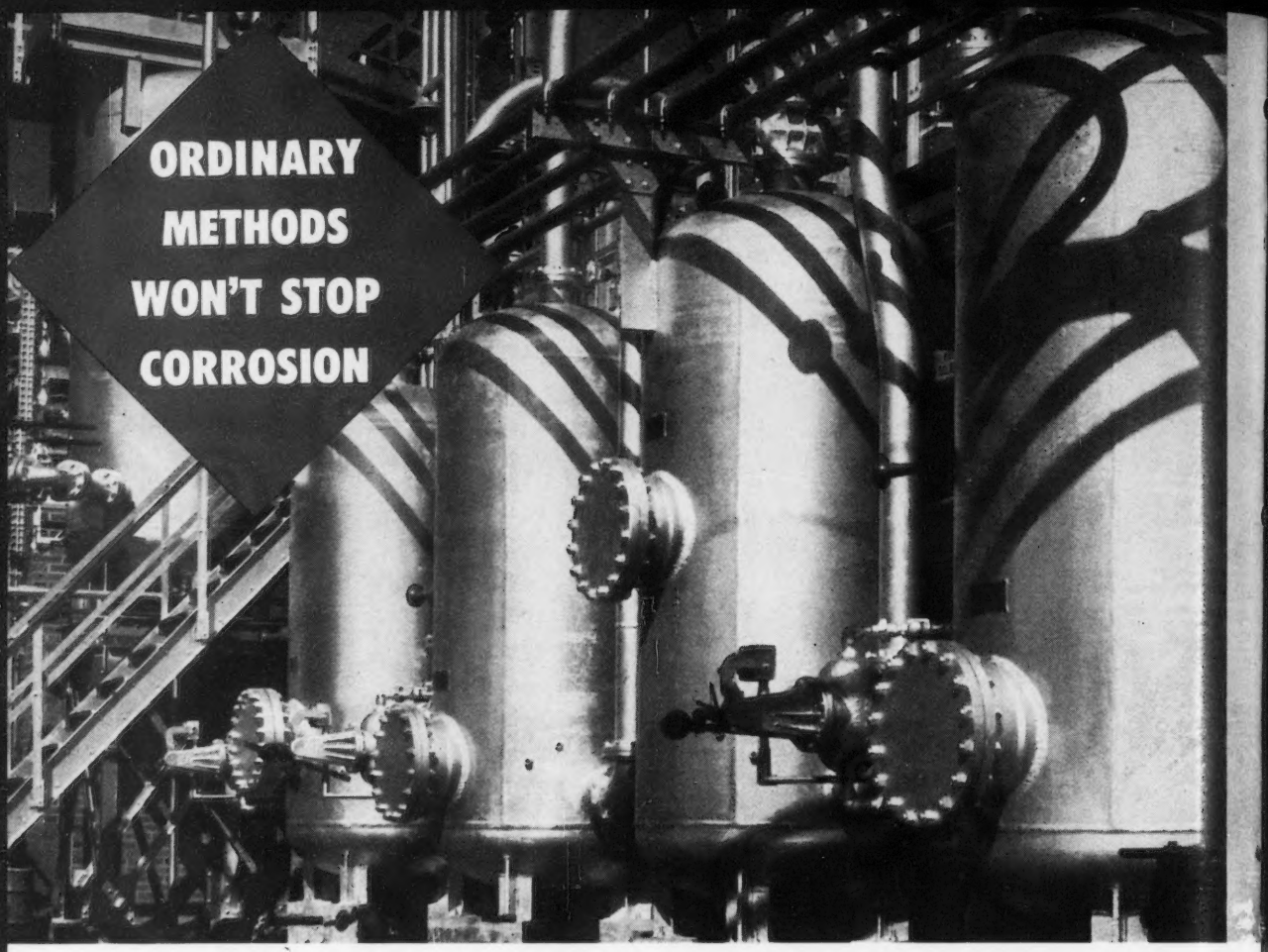
# Corrosion




# SPECIFY THE AMERCOAT METHOD— Designed to Give You *PLUS* PROTECTION

Ordinary methods for controlling corrosion usually produce the ordinary results—rapid paint failure, costly replacements, product contamination, excess down-time, and hampered production. Halfway measures and the use of one or two general purpose coatings simply cannot provide adequate protection against corrosion's ceaseless attack.

Amercoat gives you a proven method of corrosion control, assuring you proper protection through these PLUS features:

**1. Careful analysis** by a trained engineer of all the conditions present in each corrosion problem.

**2. The ONE best recommendation** for the particular problem. AMERCOAT is a complete line of coatings, each formulated to solve or control specific corrosion problems.

**3. On-the-job assistance** to your applicators and supervisors by a trained engineer. The AMERCOAT method ensures proper attention to surface preparation and application techniques for maximum protection.

**4. Complete stocks** of fresh materials always near you at one of AMERCOAT's five regional warehouses or more than 20 franchised distributor warehouses throughout the United States.

**5. Service based on experience.** The AMERCOAT method of corrosion control is the result of nearly 20 years' experience in solving or controlling corrosion problems in every major industry throughout the United States.

Write today for the name and address of the AMERCOAT representative in your area. At no obligation, he will gladly help you analyze your corrosion problems and evaluate your present control measures. If it is determined that you have a problem within our scope of experience, he will outline a complete program of AMERCOAT's PLUS protection for your plant or equipment.

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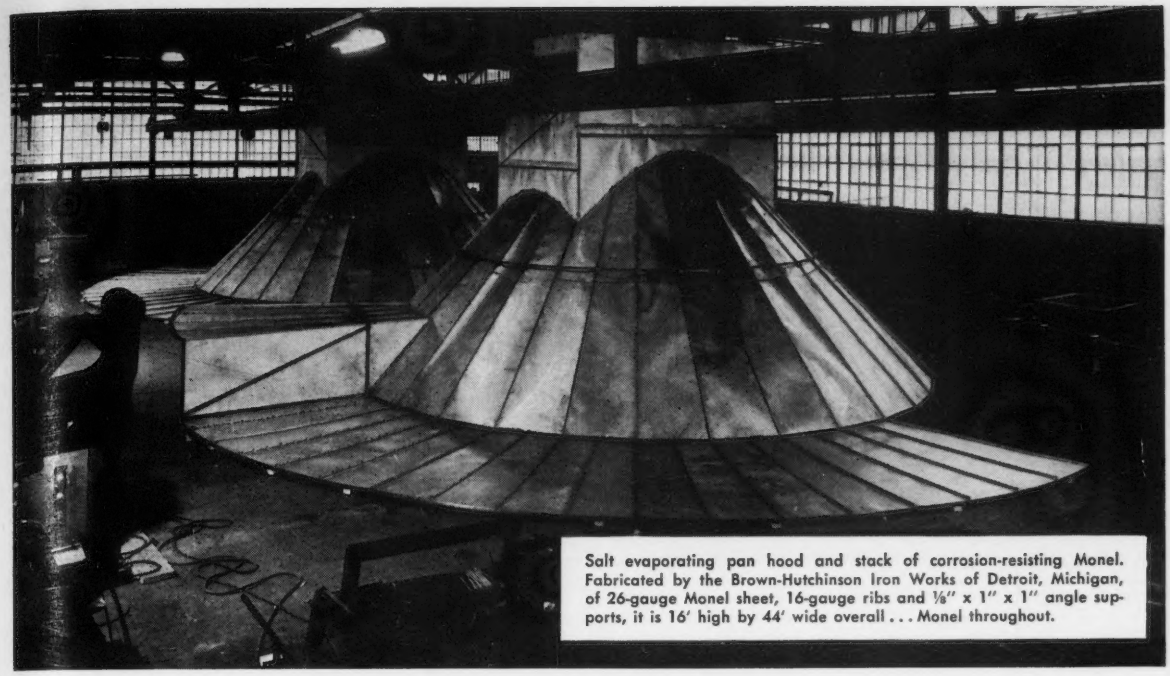

Salt evaporating pan hood and stack of corrosion-resisting Monel. Fabricated by the Brown-Hutchinson Iron Works of Detroit, Michigan, of 26-gauge Monel sheet, 16-gauge ribs and ⅛" x 1" x 1" angle supports, it is 16' high by 44' wide overall . . . Monel throughout.

# Protecting product purity with MONEL

Is corrosion putting the bite on your equipment?

Is it endangering your product purity?

Then you'll be interested in this experience of a large midwestern company.

Producing highly refined salt for the food processing industry, they needed a special material for new brine evaporating pan hoods.

They needed a material that was highly resistant to corrosion . . . because . . . corrosive salt vapors condensing on a non-resistant hood would carry heavy metal impurities back into the slurry, thus contaminating the salt.

And they needed a material that had special fabrication features. It had to have the same high corrosion resistance in weld areas as in the sheet itself.

These requirements, plus their experience with Monel® in heat exchangers, dryers, and conveyors, led them to select Monel again.

They now have four hood assemblies in use, giving excellent service in the production of a high quality salt . . . thanks to Monel.

* * *

So, if you are bothered by corrosion or have difficulty maintaining purity of product, perhaps Monel offers you a solution, too. Consult our technical staff. They will be glad to help you. Just write giving full details.

Remember, however, that because Nickel and Nickel Alloys like Monel are on extended delivery, it will pay you to anticipate your needs. Order well in advance giving necessary NPA rating and complete end-use information.

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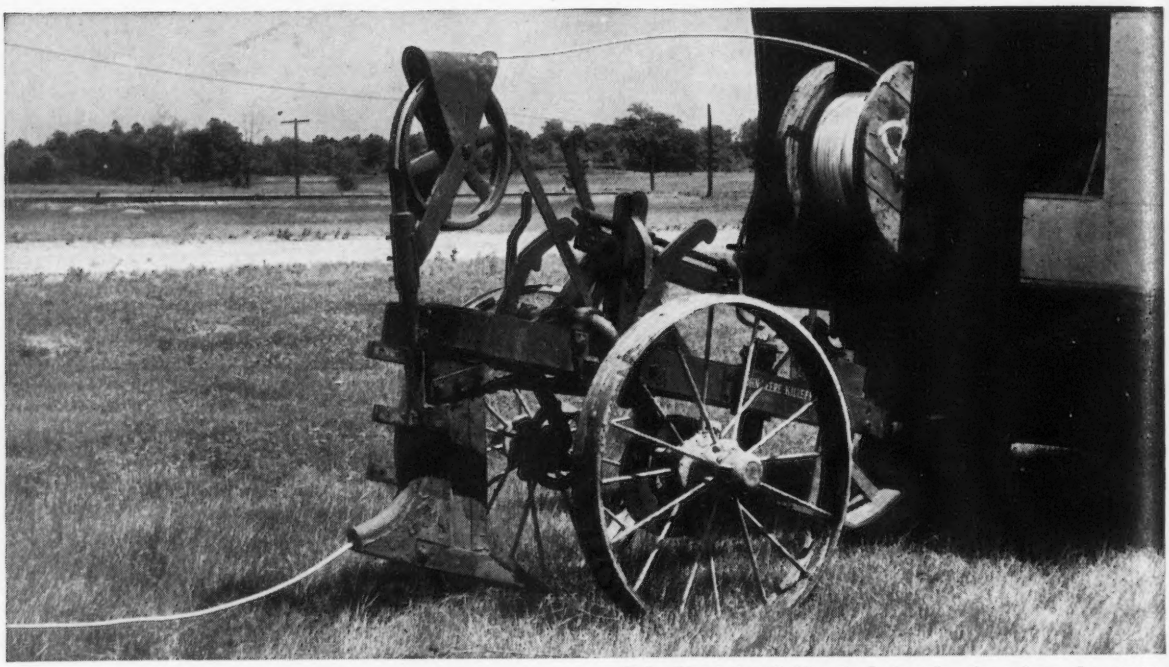
# CUT THE COST OF PIPELINE PROTECTION WITH GALVO-LINE

## Dow's Magnesium ribbon anode saves time and labor in installation



*Galvo-Line is installed by wire-laying plow drawn by truck or tractor.*

Has the high cost of anode installation discouraged you from using this most efficient method of pipeline protection? Then investigate Galvo-Line®, Dow's flexible cored, magnesium ribbon anode.

Time and labor are the big elements of cost in any anode installation. By providing a simplified method, these factors can be cut to the bone with Galvo-Line.

Up to *five miles of pipeline per day* can be protected by plowing in Galvo-Line. The installation is also simplified by the fact that the number of connections to the pipeline can be considerably reduced. Intervals of 500 to 1000 feet are generally adequate.

Galvo-Line cuts costs another way, too. It provides from three to seven times as much current per pound of magnesium installed as conventional magnesium anodes. More uniform distribution and efficient utilization of current make Galvo-Line both economical and dependable for pipeline protection.

When you plan your next protection program, figure it *two ways* . . . one with Galvo-Line. Let the facts prove themselves.

Call your nearest Dow office or Dow distributor for complete data. THE DOW CHEMICAL COMPANY, *Magnesium Department*, Midland, Michigan.

*you can depend on* DOW MAGNESIUM ANODES

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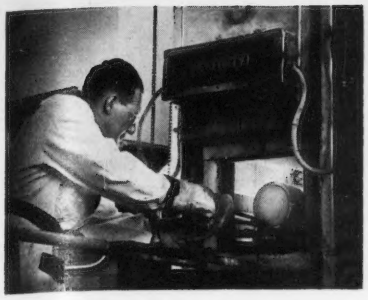

THIS MONTH'S COVER—Maynard Jones, ceramic engineer, is shown here removing from a miniature furnace in the Pfaudler Company's laboratory pilot plant at Rochester, N. Y., a specimen of steel on which glass has been fused. Experimental procedures such as this are standard practice for all new glasses as well as regular production work. The fusing temperatures range between 1350 and 1700 degrees F.

☆


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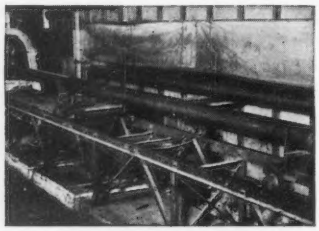
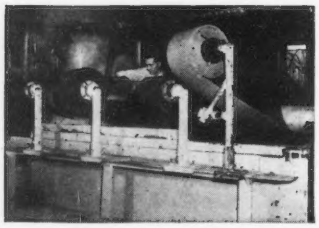
(Continued on Page vi)

# More *spi FIRSTS in c/w pipe standards

*** standard pipeprotection inc. designed and built the first plant to include all the machines and methods and procedures necessary to set the highest standards, and to produce the finest coated and wrapped pipe.**



**FIRST** plant to install short 3 foot skids between the exit from the warm primer drying areas and the coating and wrapping machines, so that the warm pipe does not have time to cool before application of the wrappings. Certain types of enamels do not bond properly to the primed pipe when the temperature of the pipe is less than 65°F.



**FIRST** and only plant to use especially designed c/w machines to produce multiple combinations . . . a maximum of 4 enamels, 3 felts or glass, and kraft. Standard's ten specifications provide combinations of materials to meet your specifications or requirements.

**FIRST** plant to establish electrical holiday detection for the entire surface of every length of your coated and wrapped pipe. This holiday detection permits the repair of all holidays, before your pipe passes final inspection.

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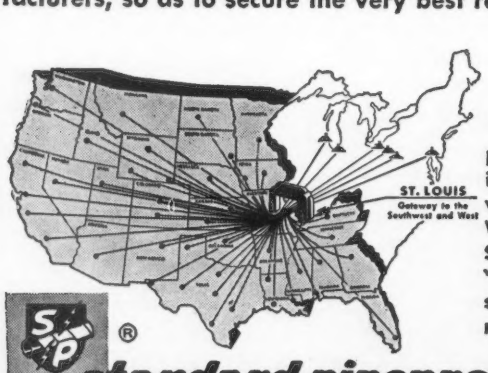


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(Continued from Page v)

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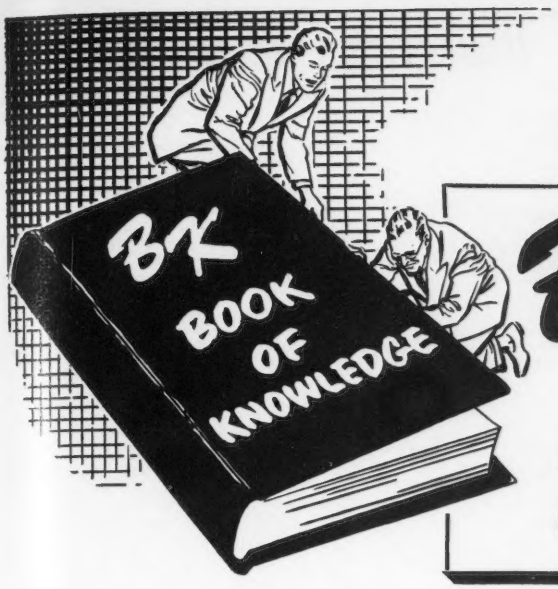


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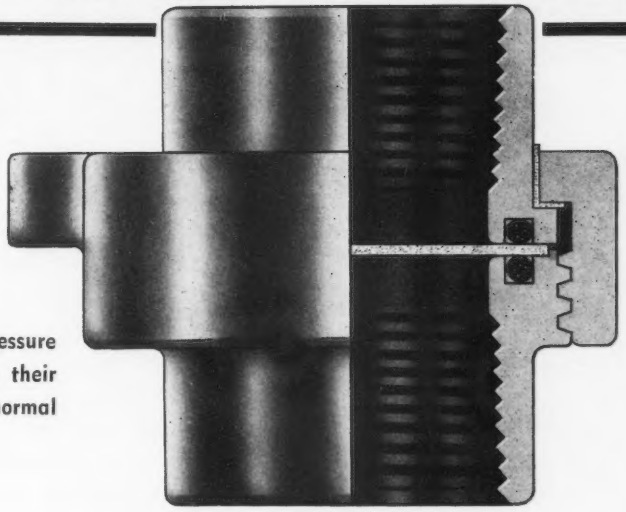

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(Continued from Page viii)

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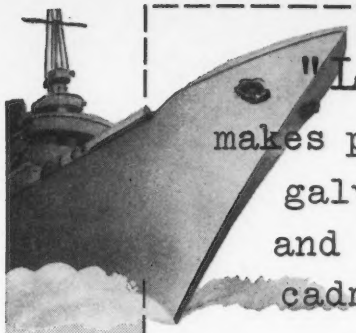

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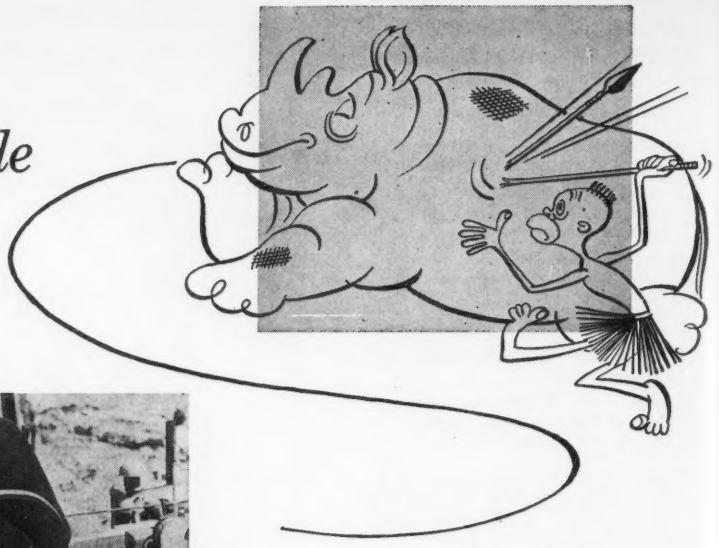

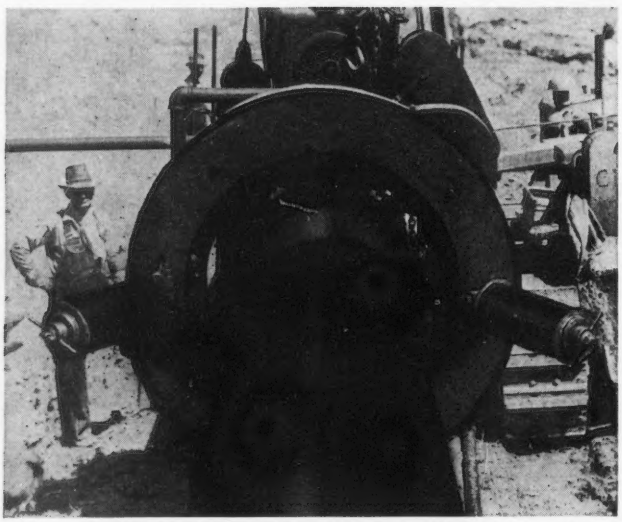

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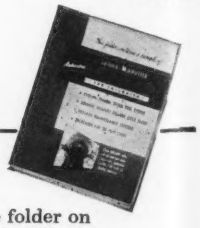

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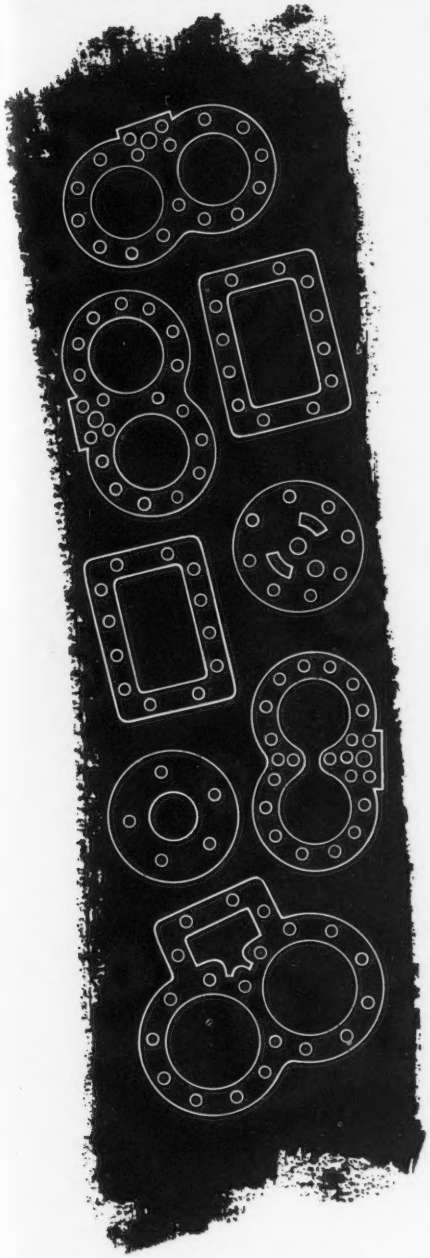

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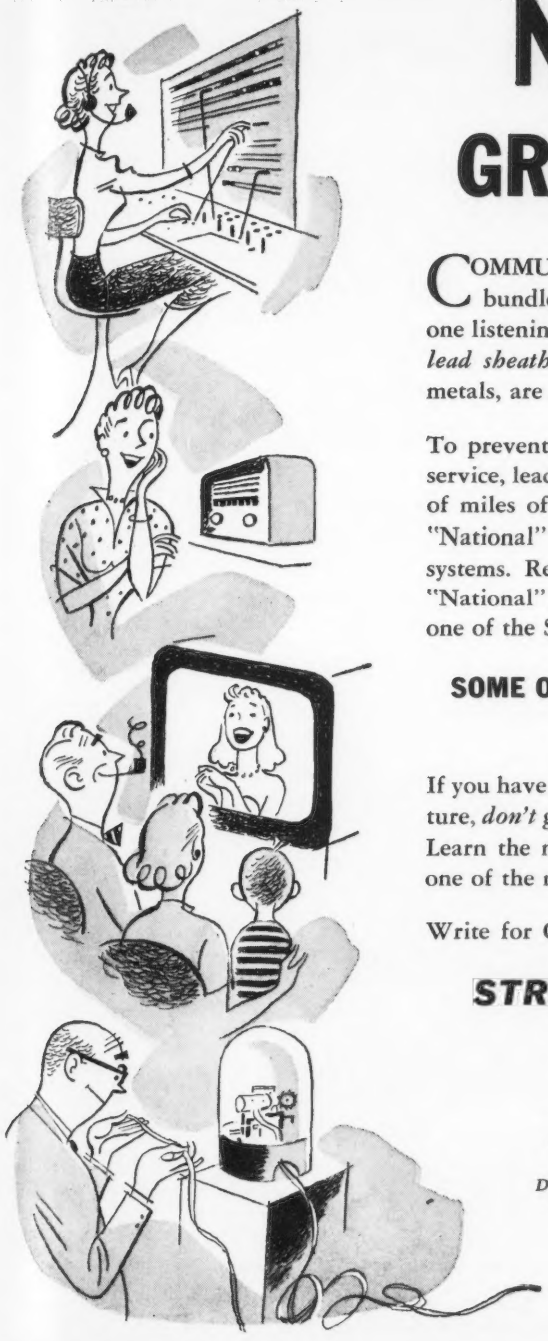

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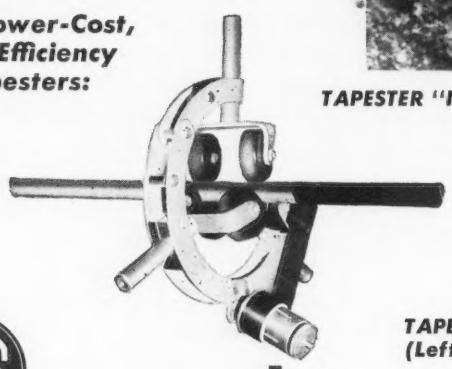
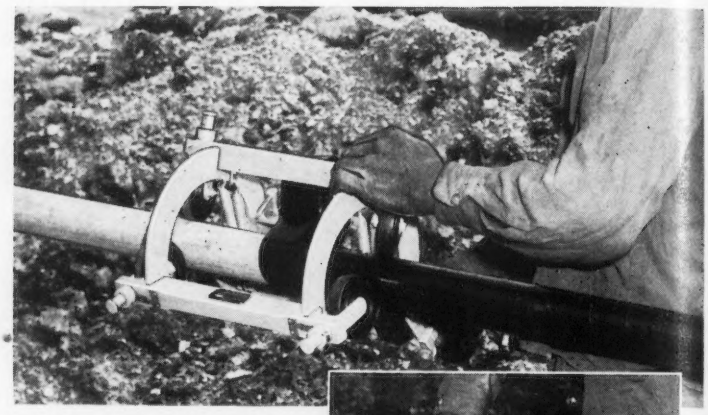
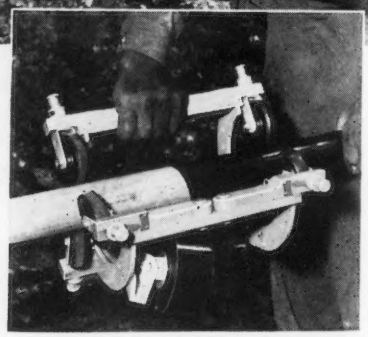




***TAPESTER "No. 2 UNIVERSAL" (Above and right)***



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## *Plastisol usage for drum linings increasing*

Drum manufacturers as well as drum reconditioners are beginning to make Unichrome plastisol-protection available to users of steel drums. And these users have begun to find the answers to better product packaging with less corrosion or contamination through these materials.

Also because of these heavy-duty linings, many newly developed products can be shipped in ordinary drums. In addition, they permit economical reuse of containers. Here's an interesting though accidental case to illustrate the point.

A producer of corrosive chemicals had several drums plastisol-lined for test. When research looked for the drums, they had disappeared. Later, they were found in the shipping department. They had been returned, inspected and re-shipped about 20 times. Regular lined drums had been good for only one to three trips.

Contact your supplier about lining *your* drums with Unichrome Series 4000 Drum Linings.

## What a good "painting" program should do

The effectiveness of protective coatings used for corrosion control in processing plants can be measured by several obvious results of the program.

(1) Has it helped lengthen service life of equipment and reduced downtime?

(2) Has it increased interval between repainting?

(3) Has it maintained a better looking plant?

Ucilon* Protective Coating Systems were developed as specialized answers to processing plant painting problems. Systems are available to withstand acids, alkalies, alcohols, organic chemicals, moisture, salts and exposure. That they make a painting program less costly and more effective can be seen from the many cases where they have given up to 5 years service under severe conditions. See more facts in your C.E.C.—or write for Bulletin No. MC-7.

**Trade Mark*

## Unichrome Plastisol Compounds winning battles against strong chemical attack and corrosion

Plastisol compounds offer engineers a material with unusually valuable design and maintenance possibilities. They provide the three properties required for durable service in a wide variety of severe applications. They can profitably supplant rubber for some end uses, and protective maintenance coatings in others.

### WHY PLASTISOLS ARE UNIQUE

(1) They are highly chemical resistant. Produced from vinyl resins and plasticizers, Unichrome Plastisol Compounds display great resistance not only to acids and alkalies, but also to water, salts, oxidizing agents and many other corrosives.

(2) They are resilient. While Unichrome Plastisol formulations can be modified to produce a coating in any range from soft to hard, the greatest number of applications seem to be in the elastic, rubbery range. In this state, Unichrome Plastisols can outclass rubbers on toughness, chemical inertness and economy for many applications. And unlike ordinary protective coatings, Unichrome Plastisols absorb abuse and impact without chipping.

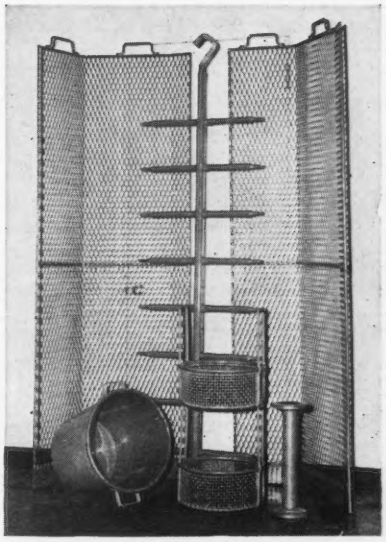
(3) Thick films can be produced. To guard against porosity in a coating and the possibility of accidental break-through, minimum film thicknesses are usually specified for protecting metals against strong corrosives. The thicker, the greater the protection. With ordinary coatings, this means applying many coats.

However, Unichrome Plastisol Compounds build up 3 mils to 3/16" thicknesses with a single prime and a single top coat. They "cure" to stable form at 350° in only 20 minutes.

### TYPICAL RESULTS

Bleach reduction chambers of a noted chemical producer were coated with a Unichrome Plastisol Compound. This user reported that the coating gave 4 times longer service than even special alloy metals before requiring maintenance!

A processing plant replaced phenolic linings in equipment for spinning synthetic fibre with a Unichrome Plastisol Compound. By so doing, they ended build-up of hard sulfide deposits.



*Tank screens, plating rack, drum, dipping basket and flanged pipe that obtained extraordinary chemical resistance with Unichrome Plastisols*

### ENDLESS OTHER USES

When battling corrosive liquids and fumes, plastisol coatings are so thick and tough they can be depended on not to break or wear through. That's why they're used to coat drain boards, to line pipe and fittings, to protect ventilating fans, ducts, solution agitators, processing baskets and the like.

United Chromium's Technical Service department will be glad to give details on a specific plastisol to meet your problem. Write, giving details of the problem.

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# THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Corrosion

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National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

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Vol. 9 July, 1953 No. 7

Technical Practices Committee 11

# Identification of Corrosion Products According to Crystal Structure Underway

By C. E. IMHOFF,* Chairman

A bibliography, primarily pertaining to methods of identification of corrosion products and to corrosion products whose identity has been established positively, is being prepared by Technical Practices Committee 11 on Identification of Corrosion Products. The committee has decided to concentrate on the accumulation of and correlation of data on corrosion products identified according to crystal structure. This makes identification independent of the methods used, most common of which are the diffraction methods and the polarizing microscope. Correlation of thermodynamic data associated with formation of the various compounds which have been identified in corrosion literature is under consideration.

The committee is undertaking to identify through correspondence some of the diffraction patterns for unidentified corrosion products which many diffraction laboratories have. The objective is to expand the list of corrosion products whose diffraction data now are available in the literature. A representative of the committee is cooperating with the American Society for Testing Materials in the expansion of its x-ray diffraction data files.

A list of positively identified corrosion products has been collected and is given below. The committee will appreciate receiving the names of similar materials along with the environmental conditions under which they are formed. Eventually, after sufficient data have been accumulated, the committee hopes these may be published.

While new members have been added to the committee, more who are engaged actively in the identification of corrosion products are needed. Anyone wishing to participate in the committee's work or to submit data is invited to communicate with the chairman.

* Research Supervisor, Chemical Laboratory, Allis-Chalmers Mfg. Co., Milwaukee, Wis. Chairman NACE Technical Practices Committee 11—Identification of Corrosion Products.

## Corrosion Products Identified by Diffraction Methods

$AgCl$
$Ag_2S$
$\alpha\ Al_2O_3$
$\gamma'\ Al_2O_3$
$Al_2O_3 \cdot H_2O$ boehmite
$Al_2O_3 \cdot 3H_2O$ bayerite
$Al_2O_3 \cdot TiO_2$
$CaMoO_4$
$CaSO_4$
$Cu_2O$ cuprite
$CuO$ tenorite
$Cu_2S$ chalcocite
$Cu_2S$ chalcocite
$Cu_9S_5$ digenite
$CuSO_4 \cdot H_2O$
$CuSO_4 \cdot 5H_2O$
$3CuO \cdot SO_3 \cdot H_2O$ antlerite
$CuCO_3 \cdot Cu(OH)_2$ malachite
$Cu(NH_3)_4SO_4$
$3Cu(OH)_2 \cdot Cu(NO_3)_2$ gerhardite
$Cr_2O_3$
$FeCO_3$ siderite
$FeO$
$Fe_3O_4$
$\alpha\ Fe_2O_3$
$\gamma\ Fe_2O_3$
$\gamma\ Fe_2O_3 \cdot H_2O$ lepidocrocite
$\alpha\ Fe_2O_3 \cdot H_2O$ geothite
$\beta\ Fe_2O_3 \cdot H_2O$
$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$
$FeSO_4 \cdot 7H_2O$ melanterite
$HgCl_2$
$Mg(OH)_2$
$NiO$ bunsenite
$2PbCO_3 \cdot Pb(OH)_2$
$PbO$
$SnO_2$
$ZnCO_3$
$ZnO$
$\beta\ ZnS$
$ZrO_2$ baddeleyite
$ZrO_2$ zirconia

# Examination of 335 Miles Of Asphalt Mastic Coated Pipe★

By DONALD E. MILTNER*

**Abstract**

335 Miles of continuously applied asphalt mastic coated pipe laid in 1941 has been examined by an extensive and systematic coating survey. This report outlines the methods of test employed in the examination; describes the test results, details typical coating failures found by inspection and discusses the coating behavior with particular reference to the prolonged effect of cathodic protection.

## I. Introduction

THE NATIONAL Bureau of Standards' comprehensive pipe-coating tests[1] have shown conclusively that the field performance of pipe line coatings can be determined only after detailed examination of operating pipe lines of appreciable age and length. The examination of representative laid coatings, selected from the vast network of coated pipe lines, offers an opportunity to add materially to the information on coating behavior and field performance. These studies would serve to supplement the recent articles in the technical press that have been concerned primarily with application methods and structural components of new coatings. Accordingly, it was felt an inspection of Socony-Vacuum Oil Company's 335 miles of asphalt-mastic coated products pipe line would be of value, especially since this coating is the longest and oldest continuous mastic application to a products pipe line in the Mid-Continent area.

The 335 miles of 6⅝ inch OD pipe line was constructed during the summer of 1941 and extends from Topeka, Kansas, to Sioux Falls, South Dakota. A light weight pipe of 14.96 pounds per foot was used in this construction because the line was to be coated in its entirety and in addition maintained under cathodic protection. This weight of pipe was selected to allow an adequate factor of safety for the normal range of operating pressures and yet provide for maximum economy in overall investment costs. Five cathodic protection rectifier units were installed soon after construction of the line was completed. Due to the high dielectric strength of this type of coating with resulting large protection coverage per unit, approximately 90 percent of the pipe line has been cathodically protected almost from date of construction. The pipe in the remainder of the line was electrically insulated at block valves so that the coating on this portion of the pipe line has never been subjected to the electrical stress of the protection voltage. This condition provided an excellent opportunity to determine the effect, if any, of cathodic protection upon the coating.

This report outlines the methods of test employed in the examination during the summer of 1950, describes the test results, details typical coating failures found by inspection and discusses the coating behavior with particular reference to the prolonged effect of cathodic protection.

## II. Methods of Examination

The three principal methods used to examine the nine year old coating were:

1. A modified Pearson[2] coating discontinuity survey.

This is an electrical method of examining buried pipe line coatings to locate discontinuities, commonly known as flaws or breaks, in an otherwise continuous coating. The survey consists of apparatus to impress a low frequency signal on to the pipe line and to monitor the amplified signal set up in the soil along the coated pipe line. The signal current is concentrated in the low resistance path offered by the exposed pipe surface at a coating break or discontinuity. This is reflected as a maximum volume point when either of the electrically coupled crew members is directly over the break in the coating. Several modifications were employed to allow the

**Figure 1—One indispensable modification of the Pearson survey was effected by providing the lead man with a pipe locator responsive to the same signal as the coating discontinuity locator. The nine year old right-of-way was largely obscured by time and agriculture. It was not uncommon in some of the taller and denser vegetated area for the discontinuity operator to not see his lead man for distances as great as three quarters of a mile.**

★ A paper presented at the Seventh Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

* Corrosion Engineer, Central Pipe Lines Div., Socony-Vacuum Oil Co., Inc., Wichita, Kansas.

survey crew to attain maximum progress per day. This was effected a) by providing the lead man of the two-man crew with a pipe locator responsive to the same audio signal so the crew could follow the pipe line very closely through the highly developed agricultural land (see Figure 1) and b) by operating between two signal sources at all times.

2. Inspection of a representative number of indicated coating failures.

The coated pipe was excavated at representative locations to determine the reason for the indicated discontinuity. The coating was inspected in detail and a record made of conditions found.

3. Coating conductance measurements on isolated sections of the gross structure.

The conductance of the coating serves to describe in electrical terms the condition of the coating over long lengths of line. The methods used were those discussed by Scott.[3]

## III. Presentation of Data and Discussion

### A. *Discontinuity Survey*

The line was traversed in its entirety except for submerged portions at river crossings.

1. A total of 204 possible coating discontinuities were staked. Stake locations were measured and recorded on sectional plats. 204 indications in 335 miles of pipe line surveyed corresponds to 1.65 pipe line miles or approximately 15,100 square feet of coating surface per discontinuity indication irrespective of cause.

2. From the total indicated discontinuities located by two different operators of the Pearson equipment working on alternate days, it was determined there is practically no difference in the final survey results of experienced operators; Operator No. 1 traversed 49 percent of the right-of-way and staked 103 coating-discontinuity indications, Operator No. 2 traversed 51 percent of the right-of-way and staked 101 coating-discontinuity indications. This close agreement of the operators' performance is indicative of the survey quality.

3. The survey crew averaged between 10.5 and 11 miles a day.

4. A considerable number of test leads were attached to the pipe at time of construction. Many were later abandoned or clipped off close to the pipe and the coating repaired. Of the 204 indications staked, 46 were identified by comparison with records as test leads with either bare ends or faulty coating repair. Three locations were excavated to confirm the identification.

5. The strength of the instrument's response to the signal, which depends upon the area of pipe surface accessible to the signal current, was recorded as either weak, moderate or strong. Of the 204 indications, 23 percent were characterized as weak, 57 percent as moderate and 20 percent as strong. Eighty percent of the strong signal response locations were selected for excavation so that the most severely affected coating would be inspected. However, several moderate and weak signal locations were also inspected for comparison.

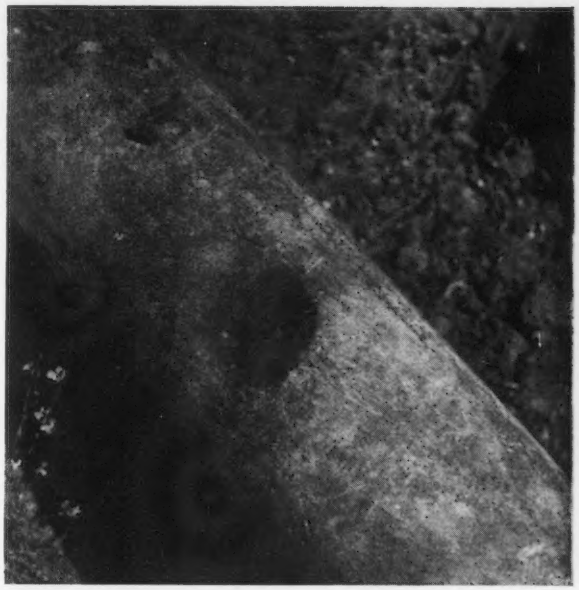

**Figure 2, Stake No. 16—The black area defines the affected coating surrounding a small 1½ inch tool cut. Note the almost perfect condition of the whitewash except at the affected area and the total absence of soil stress.**

### B. *Coating Inspection*

The discontinuities or coating failures inspected were found to be due to friable mastic, tool abrasion and other miscellaneous causes.

The coating inspections labeled "friable mastic" have a number of characteristics in common. The most important is the loss of cohesion between the asphalt and sand particles giving the defective coating a fried appearance and suggesting this classification label. This condition varies from soft mastic to complete disintegration in which the sand is clean and free of asphalt binder. In intermediate stages, the coating retains its form but readily fractures. The affected area of coating displays no obvious cause for the initial failure. However, the coating condition in this large group can be explained by assuming an initial current path (pin-hole, for example) through the coating and the subsequent effect of the cathodic protection current. The alkali produced upon the pipe surface by cathodic protection currents destroys the bond of the coating to the pipe. In time, the area of affected coating and degree of friability increases. Thus, cathodic protection adversely affects a limited area surrounding the initial defect in the coating. That this is a slow reaction is indicated by the small area of coating affected as shown in Figure 2.

The miscellaneous group consists of a case of defective hand patch (Figure 3, Stake 156), a poor bond of coating to pipe (Stake 188) and a coating flaw near a scraper trap where the coated pipe was anchored in place by U-bolts (Stake 197).

The discontinuities resulting from mechanical damage such as shown in Figure 4 are classed as tool abrasions.

Several discontinuity indications upon excavation

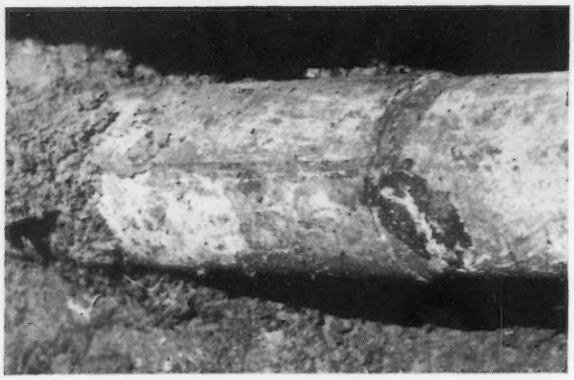

Figure 3, Stake No. 156—A hand patch of approximately 12 square inches in area adjacent to a field joint was found defective. The patch coating was brittle, was too high in asphalt content and was not properly worked into the plant coating. The coating surrounding the hand patch was friable. The inspector's red crayon mark was still evident on the intact whitewash outside the affected area.

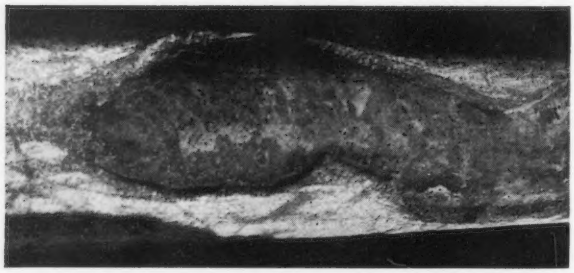

Figure 4, Stake No. 2—The mechanical coating failure was traced to a 1943 construction project. The pipe wall was scarred up to 60 percent wall penetration. Five square feet of exposed pipe surface had a light coat of rust mixed with abundant calcareous scale. The coating, where not damaged by the grader blade, was in good condition and well bonded to the pipe.

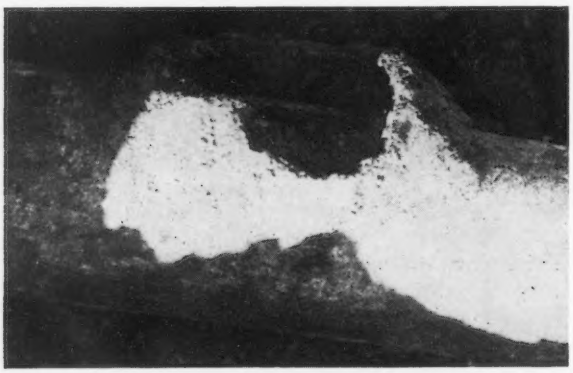

Figure 5, Stake No. 23—There was approximately a 12 inch diameter ring of cemented soil over the unbonded, soft, friable mastic coating. The pipe under the defective coating was moist with an area the size of half a dollar very bright suggesting point of initial current entry. Very little whitewash remained on the coating. The cemented soil had a strong, pungent odor.

and visible inspection showed no obvious flaw or disintegration of the coating. Thus, it is indicated that the discontinuity locator is far more critical of the coating than visual inspection methods.

Forty discontinuities were excavated and the coating inspected. As mentioned, the cause of three of these was found to be test leads. Table I herein lists the remaining 37 excavations and presents pertinent information for each location. In addition, the table includes two random excavations at points where no discontinuities were indicated by the survey.

Reasons for the discontinuity indications derived from the table are:

| | |
|---|---|
| Friable Mastic | 21 |
| Miscellaneous Causes | 3 |
| Tool Abrasion | 7 |
| None Found | 6 |
| Total | 37 |

Additional points of interest about the inspected coating, many of which are observations linked to the effects of cathodic protection, are as follows:

1. At only one location was any soil stress found.
2. At four locations, slight traces of corrosion product stains were found on the pipe surface.
3. At one location (Figure 4, Stake 2) light rust was found on the pipe surface. No pitting or shallow metal attack was found at any inspection.
4. The condition of cemented soil, such as is illustrated in Figures 5, 6, 7 and 8, was found at 14 of the 37 locations. These deposits are caused by the cathodic protection currents and are favored in the better drained soils and under conditions of high current density.
5. At four locations, obvious cathodic protection products were deposited upon the coating surface.
6. At only one location (Figure 4, Stake 2) where a large area of pipe surface was exposed was calcium carbonate found adhered to the pipe surface.

**TABLE I—Condition of Inspected Coating**

| Stake No. | Whitewash[1] | Soil Stress | Pipe Corrosion | Cemented Soil | Reason for Signal |
|---|---|---|---|---|---|
| 6 | Intact | None | None | None | Friable mastic[2] |
| 12 | Intact | None | None | None | Friable mastic |
| 16 | Gone | None | None | Yes | Tool abrasion |
| 23 | Gone | None | None | Yes | Friable mastic |
| 24 | Gone | None | None | Yes | Friable nastic |
| 37 | Intact | None | None | No | None found |
| 38 | Intact | None | None | No | None found |
| 60 | Intact | None | None | No | Tool abrasion |
| 66 | Intact | None | None | No | Friable mastic |
| 68 | Intact | None | None | Yes | Friable mastic |
| 72 | Intact | None | None | Yes | Friable mastic |
| 73 | Intact | None | None | Yes | Friable mastic |
| 75 | Gone | None | Traces | Yes | Tool abrasion |
| 107 | Intact | None | None | Yes | Friable mastic |
| 115 | Intact | None | None | None | None found |
| 116 | Intact | None | Traces | None | Friable mastic |
| 119 | Gone | Mild | None | Yes | Friable mastic |
| 126 | Intact | None | None | None | Tool abrasion |
| 133 | ..... | ..... | ..... | ..... | Tool abrasion |
| 134 | ..... | None | None | Yes | Friable mastic |
| 144 | ..... | None | None | None | Friable mastic |
| 152 | Intact | None | None | None | Friable mastic |
| 155 | Intact | None | None | None | Friable mastic |
| 156 | Intact | None | None | None | Defective handpatch |
| 171 | Intact | None | Traces | Yes | Friable mastic |
| 172 | Intact | None | None | None | None found |
| 182 | Intact | None | None | Yes | Friable mastic |
| 184 | Intact | None | None | None | Friable mastic |
| 188 | Intact | None | None | None | Poor bond |
| 194 | Intact | None | None | None | Tool abrasion |
| 195 | Intact | None | None | None | None found |
| 197 | ..... | ..... | ..... | ..... | Anchor |
| A | Intact | None | None | Yes | Friable mastic |
| B | Intact | None | Trace | Yes | Friable mastic |
| D | Gone | None | None | None | None found |
| I | Intact | None | None | None | Friable mastic[4] |
| II | Intact | ..... | Rust | None | Tool abrasion |
| RHA[3] | Intact | None | ..... | ..... | ..... |
| RHB[3] | Intact | None | ..... | ..... | ..... |

1. **Intact** signifies whitewash largely unaffected; **Gone** indicates whitewash largely removed from coating.
2. Friable mastic indicates coating affected by protective current.
3. Random holes.
4. Doubtful, coating probably unaffected.

Figure 6a, Stake B—The coating discontinuity occurred in a well drained, brown loam, 1200 ohm-cm in resistivity. There was no adherence of soil to coating except a cemented lump of soil 1½ inch in height and 3 inches in diameter. The dark area surrounding the cemented lump defines the limit of friable mastic.

Figure 7, Stake No. 119—This coating failure occurred in a poorly drained, heavy, black soil, 1000 ohm-cm in resistivity. A large spherical lump of cemented soil 10 inches high and about 1 square foot in area adhered to the coating, which was without bond to the pipe. Coating fractured readily. Mild evidence of soil stress was found. Note the curved streaks of calcareous deposits in the cemented soil.

Figure 6B, Stake B—That the coating had to be chiseled to remove it from the pipe attests to the soundness of surrounding mastic. Traces of both white deposits and rust stains were observed on the pipe. The spherical mound of cemented soil and the circular traces of white deposit and rust stain suggest that the protective current first penetrated the coating at a point.

Figure 8, Stake No. 107—The coating failure occurred in the Platte River crossing below normal river level. Continuous bailing was necessary to expose the cemented sand lump. The coating beneath the cemented sand was relatively hard with no marked separation of asphalt and sand, but the affected coating had lost bond to the pipe. Note the intact whitewash adjacent to the sand lump.

7. An analysis of coating discontinuity indication frequency with respect to distance from the rectifiers shows in general a frequency diminishing with distance from cathodic units. The cathodic protection current apparently serves by enlarging minute discontinuities, to make the locating instrument more responsive to them but this effect is subordinate to the random distribution of the discontinuities.
8. The whitewash on approximately 80 percent of the total area of coating inspected was found to be substantially intact as can be seen, for example, in Figure 8. The whitewash was gone over the area of affected coating as shown in Figures 2 and 6a.
9. The Pearson Survey over 80 continuous miles in one area revealed only one coating break. This was due to mechanical damage at a pipe line anchor (Stake 197).

10. Coating inspected at all of the strong signal locations, at one-half of the moderate signal locations and at none of the weak signal locations was found to be defective. Accordingly, the coating at 80 of the 158 staked locations (118 of which were not excavated for inspection) is considered defective. This gives an estimated rate of four pipe line miles or approximately 36,500 square feet of coating surface per discontinuity indication attributable to faulty coating.
11. The average area of all affected coating inspected was less than ⅔ square foot per discontinuity. Thus, an area of less than 50 square feet of affected coating in over 3,000,000 square feet examined can be approximated.
12. Upon completion of the detailed inspection, the defective coating was replaced at the 40 excavations. Contrary to the original intention, the remaining indicated coating discontinuities were not excavated for coating repair due to the exceedingly small area of defective coating found.

*C. Coating Conductance Test*

Three separate lengths of pipe line were selected for coating conductance tests as a means to further quantitatively characterize the gross performance of the coating.

1. The first section of coating tested was 6.8 miles in length. The coating had shown no discontinuities in the Pearson survey. The pipe line had never been under cathodic protection. Soil resistance averaged 5800 ohm-cm. Coating conductance was found to be 1.01 micromhos per square foot.

2. The second section of coating tested was 6.0 miles in length. Like the first section tested, the pipe line had never been under cathodic protection or shown any discontinuity in the traverse. Soil resistance averaged 5500 ohm-cm. Coating conductance was found to be 1.54 micromhos per square foot. This section of pipe line like that above was laid in the last phase of construction of the entire pipe line.

3. The third coating tested was laid in the first phase of construction. Fifty-five coating discontinuities were staked in the fifty miles tested.

This section of the pipe line had been under cathodic protection since date of laying. Soil resistance averaged 2600 ohm-cm. Coating conductance was found to be 6.6 micromhos per square foot. The higher value of conductance can be attributed in part to the high discontinuity rate together with possible grounding of some flooded block valves.

For comparison, records show coating conductances ranging from 0.21 to 4.02 micromhos per square foot with an average of 1.21 micromhos per square foot. This average was derived from measurements on several short lengths of mastic coated pipe, totaling sixty miles and ranging from 4 to 25 miles in length and from 3 months to 5 years in age. Also, Kleinheksel[4] reports an average conductance for asphalt-mastic coating of 0.71 micromhos per square foot for 306 miles of 6 and 8-inch pipe, respectively one and two years old.

## IV. Summary

1. The Pearson type instrument is highly efficient for detecting discontinuities in coatings of high dielectric strength such as asphalt-mastic. In the hands of experienced operators, it will indicate coating failures that often cannot be confirmed by visual means.
2. This survey indicates that the inspection made of the coating during manufacture and construction of the line was of a high order. Probably many of the discontinuities attributed to pin-holes that were enlarged by the cathodic current applied would have been nonexistent if the more powerful modern holiday detectors had been available in 1941.
3. The rate of discontinuities was found to be one per four miles of pipe line. This exceedingly low rate substantiates the high quality of the coating found in the examination.
4. The coating was almost completely unaffected by soil stress with the whitewash largely intact.
5. The total area of coating adversely affected from any cause whatsoever was approximately 50 square feet in over 3 million square feet of pipe coating.
6. The low discontinuity rate per mile and small area of affected coating shows that moderate protective voltages have not affected the sound coating for at least nine years.
7. The low values of coating conductance found on this nine year old coating indicate that the coating has absorbed moisture at a very low rate and confirmed the small number and area of discontinuities found by the Pearson method.

## V. Acknowledgment

The author acknowledges and appreciates the cooperation afforded in this investigation by the Bechtel Corporation, California Research Corporation and the H. C. Price Company. The assistance of Dr. Gordon N. Scott throughout the investigation is also acknowledged and appreciated.

## References

1. K. H. Logan. *Proc. API*, **21** (IV) 32 (1940).
2. J. M. Pearson. *Petro. Eng.*, **12** (10) 82 (1941).
3. Gordon N Scott. *Proc. API*, **29** (V) 19 (1949)
4. Stanley Kleinheksel. *Petro. Eng.*, **22** (3) 87 (1950).

## DISCUSSION

**Questions by R. L. Bullock, Interstate Oil Pipe Line Co., Shreveport:**

1. Were there any holidays detected at bends in the line?

2. Isn't it possible that the corrosion products noticed on the pipe were due to oxidation after the pipe was exposed?

**Replies by Donald E. Miltner:**

1. Particular attention was given to the location of the coating failures with respect to pipe line overbends, sags and side bends. Study of the completed field reports showed no coating failures where the coated pipe had been bent to conform with the ditch.

2. Possible. At four locations, slight traces of cor-

rosion product stains were found upon the pipe surface. When the pipe surface was exposed to oxidation by the removal of the defective coating, the stains became more evident as the oxidation proceeded.

**Question by H. C. Van Nouhuys, Southeastern Pipe Line Co., Atlanta:**
On what basis were rectifiers installed?

**Reply by Donald E. Miltner:**
Five cathodic protection rectifiers were installed soon after construction of the pipe line was completed. Three of these units were placed at major river crossings and one unit was positioned to cathodically protect a lateral that traverses an industrialized area. The fifth cathodic unit was installed at such a point that the five installations would cathodically protect approximately 90 percent of the entire 335 miles.

**Questions by W. L. Kinney, Electro Rust-Proofing Corp., Chicago:**
1. In reference to your statement that with normal pipe to soil potentials no damage to the coating would result from the use of cathodic protection, what do you consider as normal potentials?
2. What was the minimum pipe to soil potential?

**Replies by Donald E. Miltner:**
1. The low discontinuity rate per mile and the small area of affected coating indicate that moderate protective voltages have not affected the sound coating for at least nine years. Maximum pipe-to-soil potentials measured near the rectifier units were approximately 4.0 volts.
2. It is intended that minimum pipe-to-soil potentials will not be below 1.0 volts and definitely not below 0.85 volt for adequate cathodic protection. Reference electrode is Cu-$CuSo_4$ in all measurements.

**Questions by Lt. R. F. Schmoker, U. S. Naval Academy, Annapolis:**
1. What is the thickness of this coating?
2. In place cost per foot?

**Replies by Donald E. Miltner:**
1. The standard specified coating thickness for 6⅝-inch OD pipe is 7/16-inch on the plant applied coating and 11/16-inch on the field joints.
2. The cost of coating of this type may not be expressed in any general rule as the conditions, quantity and size of pipe involved control the cost.

**Question by Lyle R. Sheppard, Shell Pipe Line Corp., Houston:**
Did other coatings in this area evidence soil stress?

**Reply by Donald E. Miltner:**
We do not have performance records on other type coatings through the area traversed by this survey.

**Question by O. W. Wade, Transcontinental Gas Pipe Line Co., Houston:**
After your experience with improper composition of mastic material in patching field joints, do you propose a method for controlling the composition of this material for mastic coating in the field?

**Reply by Donald E. Miltner:**
The control of composition of mastic for field application is now handled by one of the three following methods:
a. A 100-foot water bath with belt conveyor is provided for cooling thin strips of plant-mixed asphalt mastic as it comes from a hopper. The water containing white wash material and lime dust is sprayed on the cooled mastic just before the material is sacked. The manufacture is strictly controlled.
b. Mastic is ground after being manufactured in accordance with proportions set forth in specifications through a continuous mixing operation. Material is sacked and provided to field crews.
c. Aggregate is compounded in conformity to specifications through a continuous mixing operation, no asphalt is added. This "dry-mix" is provided field crews in calibrated bags for the proper addition of asphalt by proportionate weight in the field mixing equipment.

**Questions by R. F. Hadley, Sun Pipe Line Co., Philadelphia:**
1. What was the percent of asphalt in bad mastic?
2. What was the percent of asphalt in good mastic?
3. Was mastic bad at edge of large breaks?
4. How were conductance measurements made?

**Replies by Donald E. Miltner:**
1. The percent of asphalt in bad mastic was variable.
2. The percent of asphalt in good mastic was 12 percent to 13 percent by weight in accordance with specifications. In field applied coating, the addition of asphalt up to a maximum of 15 percent by weight is permitted.
3. No—see Figure 4. The coating, where not damaged by the grader blade, was in good condition and well bonded to the pipe.
4. Conductance measurements were made in accordance with proceedings of the API, 29 (V) 19 (1949).

Figure 6—Adjusting a pole mounted rectifier.

# Magnetic Amplifier Controls for Rectifier Protecting Underground Metallic Structures Cathodically ★

*By OLIVER HENDERSON*

## The Nature of the Problem

THE INCREASING use of trackless trolleys and gasoline busses in Cleveland and the resulting elimination of some of the ground return trolley car routes is changing the aspect of the electrolysis situation in certain areas of the city.

Instead of perhaps a dozen locations at which heavy concentrations of stray rail currents formerly existed there are numerous scattered spots which have unsatisfactory electrolysis conditions but which involve only a small amount of current individually.

The problem was solved formerly in Cleveland largely by placing heavy copper bonds between the telephone cable sheaths and the negative busses in the railway substations. But with the tapering off of this type of problem there have come to light numerous small areas remote from any railway substation which are in need of some form of drainage. These unsatisfactory situations are often the result of stray current "end effects."

## Forced Drainage Is Solution

The solution for the difficulties encountered at these scattered areas often is the use of forced drainage to a remote ground and employment of a small rectifier on the order of 10 amperes output. It is well known that overdrainage of telephone cable sheath at such locations will attract current from nearby metallic underground structures of other utilities thereby rendering them anodic or positive to earth and subjecting them to accelerated corrosion. While it is generally quite easy to avoid this adverse effect on neighboring structures by adjusting the output of the rectifier for the optimum output current, this adjustment will be correct only for the particular time of the day at which the adjustment was made. The amount of current which constitutes correct drainage may vary considerably with the time of day due to frequent changes in the amount and direction of the stray earth current throughout the railway traffic cycle. The variations are due to the peaks in passenger loads and the related scheduling of the railway substation operation. In the City of Cleveland from two to seventeen substations may be in

**OLIVER HENDERSON—Foreign Wire Relations Engineer for The Ohio Bell Telephone Company, Cleveland, Mr. Henderson's work includes coordination of structural, inductive, protection and electrolysis analysis problems involving telephone company plant and that of other utilities. A graduate from Case Institute of Technology in 1922 with a BSEE, he obtained his electrical engineering degree from Case in 1943 for his work on carrier telephone systems on cable conductors. He has worked for Ohio Bell since graduation and is a member of the Cleveland Electrolysis Committee, composed of 12 major utilities in northern Ohio.**

★ A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

## Abstract

This paper covers the initial attempt on the part of the Ohio Bell Telephone Company to use a magnetic amplifier to give continuous control of the output of a copper-oxide rectifier used for cathodic protection of underground lead covered cables.

The controlled rectifier was designed for use at a location where stray current "end effects" were damaging underground telephone cables and municipal light cables and were threatening high-pressure water mains.

When properly adjusted, the output of the rectifier will increase or decrease automatically so that at each instant the amount of forced drainage will be adequate to protect the underground telephone cable sheath but will not be in excess of the value at which neighboring underground metallic structures would become anodic and would thus become subject to corrosion.

For satisfactory operation the amplifier had to be designed to give a large gain so that a change in the control voltage of only .2 volt (+.1 to —.1 volt) would be sufficient to vary the output of the rectifier from practically zero current to full rating. In the installation described in this paper the gain of the magnetic amplifier is in the order of 12,000.

The magnetic amplifier type of control is well suited to outdoor installations subject to wide changes in temperature and at remote locations where frequent maintenance inspections are not feasible.

The magnetic amplifier has advantages over other available control devices which accomplish this same purpose in that it has no moving parts, no vacuum tubes, batteries, motors, relays or contactors. The magnetic amplifier gives a continuous output control which is superior to the stepped increment changes that result from relay or contactor operation.


operation at any one time depending on the varying demand for railway power.

It is evident that a rectifier used for forced drainage and adjusted to any given amount of output current would be correct for only a small fraction of the time. With a fixed output, overdrainage will probably occur during light railway loads and inadequate drainage may result during the peaks of traffic. The proper drainage could, however, be maintained by a rectifier whose output is automatically and continuously variable from zero to maximum under the control of the potentials of the structures being protected.

### Other Regulating Devices

Devices which accomplish this end already are in use, deriving their control from selsyn motors, contactors, relays, vacuum tube amplifiers, etc. These designs were apt to be elaborate, expensive and require frequent routine maintenance. Any solution of the problem is rendered difficult by the fact that the device used must be so sensitive that only a .2 volt (+.1 to —.1 volt) swing in control voltage must produce a full swing in the range of the output current.

It occurred to the writer that a magnetic amplifier (saturable reactor) could be designed to give the necessary gain. Such an arrangement has the following advantages over motor drives, contactors or vacuum tube controls:

No short life parts such as vacuum tubes or batteries.
No moving parts or motors.
No relays or contactors.
Relatively inexpensive component parts.
Continuous control, not stepped changes.

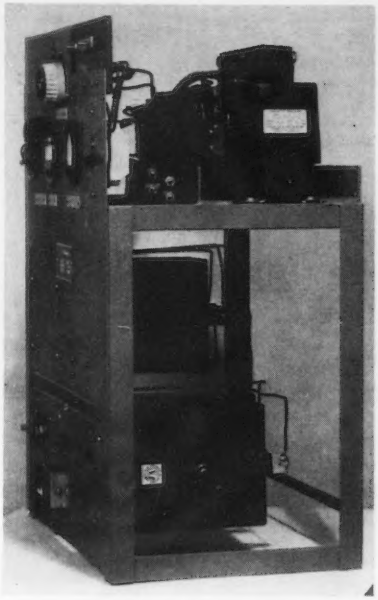

Figure 1—Assembly of magnetic amplifier and selenium rectifier with the associated control panel.

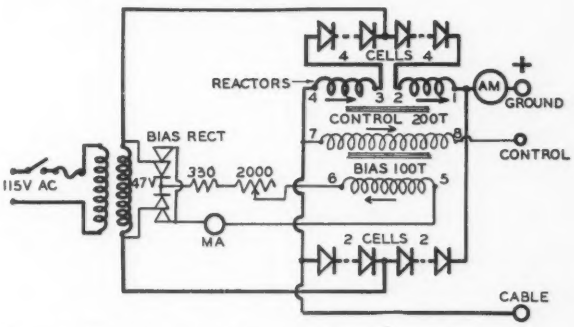


Figure 2—Wiring diagram of the magnetic amplifier and the bridge type selenium rectifier.

Small temperature effects.
Small AC supply voltage regulation effects.
Can be enclosed in a weatherproof case.
Design is applicable to various current outputs.

Consequently, the available types of magnetic amplifiers were investigated and the most promising arrangement was selected. The saturable reactor, selenium rectifier and power transformer were supplied by the Vickers Electric Division having been built by them to the writer's requirements. The balance of the equipment and the weatherproof case were provided and assembled by the Harco Corporation of Cleveland.

### Description of Apparatus

Figure 1 is a photograph of the rectifier assembly with its control panel. The unit was later installed in a weatherproof cabinet 13 x 17 x 27 inches.

The circuit of the amplifier is the subject of patents or patent applications which the Vickers Electric Division either owns or is under license to use.

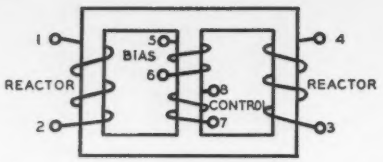


Figure 3—Arrangement of the core and windings of the saturable reactor portion of the amplifier.

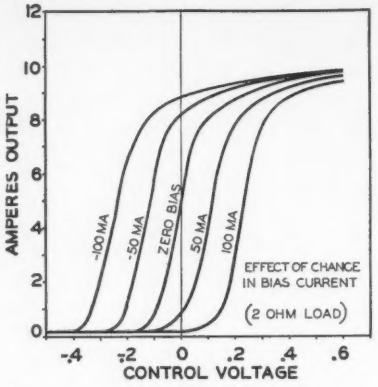


Figure 4—Effect of different values of bias current on output of the rectifier into a fixed 2-ohm load.

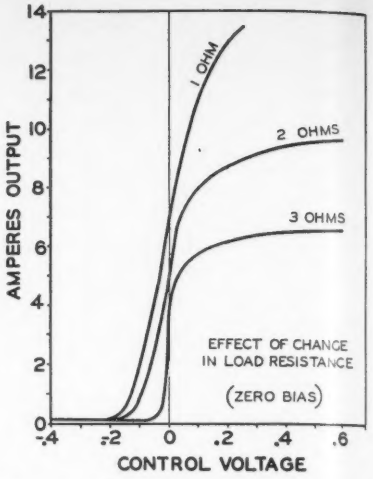


Figure 5—Effect of external load resistance on rectifier output.

Figure 2 is a wiring diagram of the circuit arrangement employing a magnetic amplifier. It consists essentially of a bridge or full wave type of rectifier using selenium discs. Saturable reactors have been added to two arms of the bridge. By controlling the magnetic saturation of these two reactors the voltage drop across their terminals can be varied thus controlling the voltage impressed across the rectifier discs. This voltage in turn determines the DC current output of the unit.

By placing the reactors in the DC arms of the bridge rather than in the external AC circuit, the desaturation is avoided that would occur in an AC circuit during the half cycle reversals. This arrangement, plus the fact that the response time is not a limitation in this application, makes an important contribution to the large power gain of the amplifier.

As shown in Figure 3, the two reactors are wound on the outer legs of the same core and the control and bias windings are on the central leg of the core and are, therefore, common to both reactors.

The control winding consists of 200 turns and serves to control the degree of magnetic saturation. As shown in Figure 2, the current flowing in this winding is determined by the potential difference between the telephone cable sheath and the nearby metallic structure in the interest of which the amount of forced drainage is being controlled.

The bias winding, consisting of 100 turns, is DC operated and is connected to a separate small selenium bridged rectifier through a radio type potentiometer and a protective resistor. The function of the bias winding is to bring the operating range of the main rectifier and reactors into the range of the control voltages. It will be shown later that small changes in the resistance of the external load on the unit causes a shift in the control characteristics. This and other factors can be compensated for by the bias winding. It is to be noted that for some applications the polarity of the bias winding can be reversed if necessary to make it magnetically aiding to the control winding. A locking type reversing switch is incorporated into the design to facilitate this change in bias.

## Theory of Operation

In the mitigation of stray current electrolysis situations, it is generally conceded that the structure-to-earth potential of an underground structure must be reduced to +.1 volt or less if the structure is to be considered satisfactorily protected against accelerated electrolytic corrosion.

Therefore, the forced drainage applied to an underground telephone cable sheath should not exceed the amount that will cause the nearby structures of other utilities to exceed +.1 volt to earth. On the other hand, sufficient drainage should be applied to the telephone cable so that its lead sheath to earth potential does not exceed +.1 volt, otherwise the drainage will be inadequate to protect the telephone plant.

It follows from the above, that the potential difference between the nearby structures and the telephone cable sheath should be kept within the accepted safe range of +.1 volt to —.1 volt. This gives a maximum swing of only .2 volt to be applied to the control winding and to which the output of the rectifier must respond with a full swing between zero amperes and its maximum rating. To accomplish this, the magnetic amplifier for the initial installation, herein described, was designed to give a power amplification of about 12,000. This large power gain is indicated by the steep slope of the straight line portion of the curves plotted in Figure 4 and Figure 5.

A bias winding has been included in the magnetic amplifier which normally is connected inductively opposed to the control winding. A small separate bridged rectifier provides DC bias current which can be varied over a range of 0 to 100 milliamperes by means of a radio type potentiometer. The function of the bias winding is to shift the effect of the control winding so that the operating range of the amplifier coincides with the +.1 to —.1 volt range of the control voltage. This adjustment is necessary for optimum operation because a small difference in the external load resistance will cause some shift in the position of the operating characteristics. The effect

of different values of bias current is shown by the family of curves plotted on Figure 4.

It is also to be noted in Figure 4 that if the voltage applied to the bias winding is reversed the shift is continued further to the left and in an orderly fashion. This possibility will prove useful in some applications to offset the shift to the right caused by an external load of a higher than usual value of resistance.

Figure 5 is a family of curves which illustrates the effect of three values of external load resistance. The larger the load resistance the greater is the shift to the right of the operating characteristic. The load resistance is normally kept as low as feasible by the selection of large size copper drainage wire and the proper preparation of the ground bed. The initial value of the load resistance is not accurately predictable and the final resistance is subject to later changes due to aging of the ground bed and to seasonal variations in the conductivity of the soil.

As shown in Figure 5, the maximum current output drops as the load resistance is increased. This is due to the simple application of Ohm's law and is not peculiar to the magnetic amplifier type of control.

## Field Installation

Figure 6 is a photograph of the rectifier mounted in a weatherproof box on a municipal power pole.

The installation was made near the lakefront at Cleveland where considerable current was leaving the underground cable sheath of the telephone company and the cable sheath of the municipal power company and was flowing to earth due to end effects. Forced drainage was decided upon as a remedial measure as a result of joint surveys by the two utilities.

A single rectifier was installed for the joint benefit of the underground cable sheaths of both utilities. Since excessive forced drainage at this location will tend to jeopardize the nearby high-pressure water mains, the control potential is obtained by a connection to the riser of a fire hydrant.

Figure 7 is a schematic of the connection of the controlled rectifier to the telephone and power cable sheaths and the remote ground bed. This arrangement was later modified by the insertion of the noise suppression filter, shown in Figure 8, in the rectifier output. The total load resistance is .95 ohms which is the measured sum of the combined resistances of the two cables to earth, the resistance of the filter choke coil and of the drainage wire and the resistance of the ground bed.

The ground bed consists of five 2-inch x 80-inch graphite anodes set in 10-foot holes, 15 feet apart and backfilled with a suitable mixture of coke breeze and lime. The initial resistance of the ground bed alone measured .65 ohms.

By keeping the load resistance low, the maximum current output for which the rectifier was designed is made available. This can be verified by examination of Figure 5 as previously discussed under theory of operation.

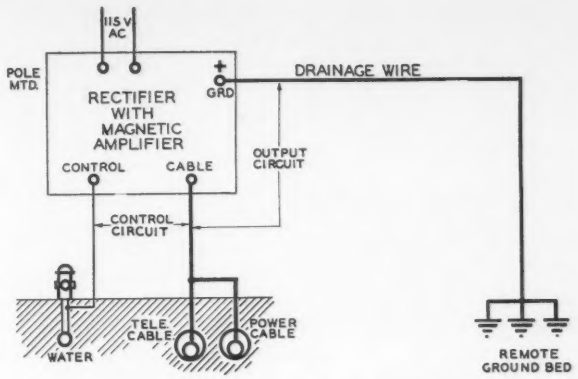


Figure 7—Schematic diagram of external connections from rectifier.

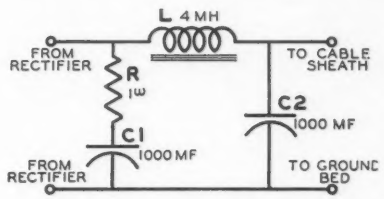


Figure 8—Schematic diagram of external noise suppression filter.

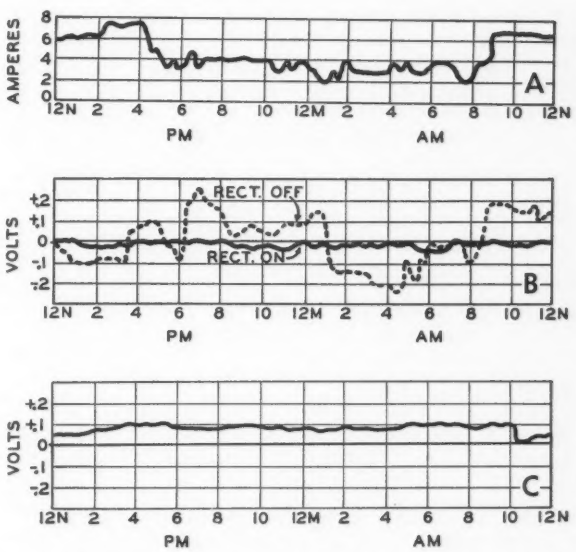


Figure 9—Curves replotted from 24-hour smoke chart recordings. A—Variation in rectifier output. B—Cable to earth at critical location. C—Water main to earth potentials.

## Noise Possibilities

In a simple rectifier having a resistance controlled output, the direct current is actually a series of unindirectional waves which are substantially half sine waves. However, in a magnetic amplifier controlled rectifier, the DC output consists of half sine waves only at maximum current. The wave becomes more and more distorted as zero output is approached. In this respect it resembles a grid controlled rectifier. This distortion of its wave form results in numerous harmonics which, if impressed

on a telephone cable sheath, may be induced as noise into the telephone conductors.

At the location described above in this paper, telephone noise was experienced at two nearby private branch switchboards. This was corrected by inserting a filter, shown in Figure 8, into the rectifier output.

Use of the filter in the rectifier output was optional and could have been avoided, if desired, by installing available noise suppression capacitors at each of the two switchboards at which noise was experienced.

The constants of the filter elements are as follows:

"L" W. E. Co. 7A choke coil, 4 millihenrys, .014 DC ohms
"C1" W. E. Co. KS 6847 dry electrolytic capacitor, 1000 mf
"C2" W. E. Co. KS 6847 dry electrolytic capacitor, 1000 mf
"R" 1 ohm, 200 watt resistor

The resistor R in the filter improves the power factor of the load and thereby results in a reduction in the AC input current. It also acts to protect the rectifier in the event of a short circuit in capacitor C1. A value larger than one ohm tends to reduce the effectiveness of the filter.

The filter was installed in a separate metal box. 7¼ x 12½ x 18 inches.

Since the conditions giving rise to the noise at the two telephone switchboards discussed above were somewhat unusual, it is not expected that a noise suppression filter in the rectifier output will be required usually.

## Field Performance

Initial adjustments were made during regular working hours without any attempt at correlation with the railway load currents existing at the time or the number or location of the railway substations then in operation.

Tests indicated that optimum control at this particular location is obtained with the bias winding reversed and the bias current adjusted to 100 milliamperes.

After the adjustments were completed, 24-hour recordings were taken to determine the potentials to earth of the telephone cable sheath, the municipal power cable sheath and the high-pressure water main at all critical locations. These charts indicated that the rectifier output current was varying from moment to moment to give adequate protection to the lead cable sheaths without jeopardizing the nearby water main.

On Figure 9 the data from four of the more pertinent 24-hour smoke charts has been plotted.

Figure 9 A shows fluctuations of the output current of the rectifier. A maximum of 7 amperes and a minimum of 2 amperes occurred during the 24-hour cycle. This change in current and the smaller excursions were found to correlate with the variations in the control voltage over the same period.

Figure 9 B shows the cable sheath to earth potentials at the manhole at which the electrolysis situation had been the most critical. With the rectifier in operation the sheath is slightly negative at all times, which is the ideal condition. The sheath to earth potentials with the rectifier not in operation has been superimposed on Figure 9 B and shows that the sheath was anodic without the rectifiers for about 16 hours out of the 24 and was, therefore, formerly subject to accelerated corrosion.

Figure 9 C is a plot of the potentials of the high-pressure water main to earth with the rectifier in operation. This pipe has always been somewhat anodic to earth. Because of the proximity of the water main to the telephone cable sheath, any forced drainage of the cable will tend to attract current from the pipe thus making it still more positive to earth.

As shown on Figure 9 C, the automatic control of the rectifier is such that the increased positive potential of the water main never exceeds +.1 volt measured to an iron ground rod. This condition is considered satisfactory in view of the large surface area of the pipe in direct contact with the earth.

During the year the rectifier has been in operation, check tests have been made and its operation found to be very stable. Some changes were to be expected because of aging of the ground bed and soil temperature variations. However, no changes were observed sufficient to justify an alteration of the original adjustment of the rectifier controls.

## Conclusion

The magnetic amplifier (saturable reactor) type of rectifier control is entirely satisfactory for the mitigation of electrolysis problems of the type described.

No unanticipated difficulties were encountered in the initial installation and no significant maintenance has been required during a year of operation.

Costs of the first installation, being experimental, was necessarily increased by the extra supervision given to it. However, on subsequent installations the cost should be normal. Indications are that the costs will be considerably less than the indicated costs on comparable devices employing other control methods.

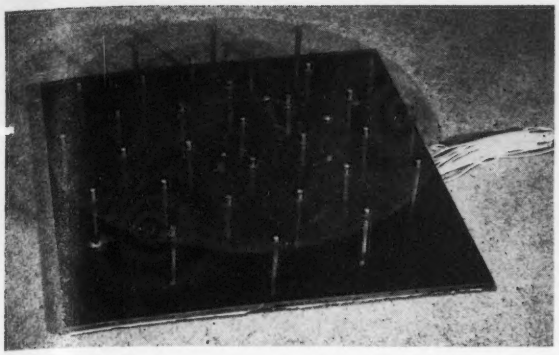

Figure 1—Model of corroding tank bottom.

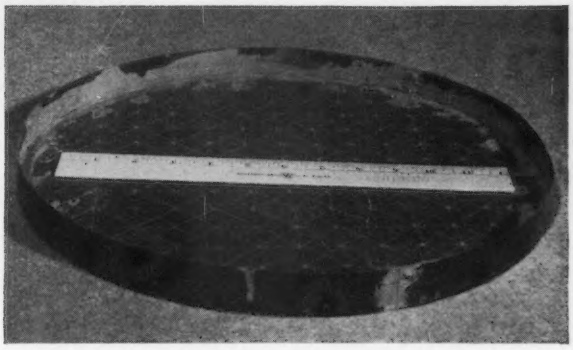

Figure 2—Model of tank bottom coating or pad.

# Cathodic Protection Applied to Tank Bottoms*

By SCOTT P. EWING* and J. S. HUTCHISON*


## Abstract

Laboratory studies are presented in which a method was devised for determining cathodic current requirements for the protection of storage tank bottoms. This method involves the determination of current distribution efficiencies on tank bottoms from four terminal resistivity measurements. For the purpose of this report the efficiency of current distribution may be defined as the ratio of the current density at the tank bottom center to the average current density. This method offers the corrosion engineer a possible method for estimating the resistance and effectiveness of various tank bottom coatings and pads. Its use offers possibilities for determining the current required to protect either a coated or uncoated tank bottom.

Initial tests of the method were made on three storage tanks near Houston, Texas. Since measurements were made on empty storage tanks in which the release of load had produced warping of the bottom, there was some inconsistency between test data and calculated values. This investigation also revealed that current-potential curves were not reliable in fixing adequate cathodic current values for tank bottom protection. Due to limited number of field tests made, this method should not be considered completely proved at this time.


## I. Introduction

THE PURPOSE of this investigation was to devise methods for the determination of cathodic current requirements for tank bottom protection. The principal difficulty in the cathodic protection of tank bottoms is that the current density is least on the inaccessible central part of the tank. The potential at the tank bottom center can be measured by tunneling under the tank or by drilling holes in the bottom when the tank is empty. However, in actual practice empirical rules are used. One of these rules is that the IR drop through the soil under the tank is about one millivolt per foot.[1] This rule has been confirmed by James and Featherly.[2]

However, potential measurements with reference to a copper-copper sulfate electrode on a 100-foot diameter tank bottom by the engineers of the Interstate Pipe Line Company gave —0.675 volt everywhere before cathodic protection was applied. Two months after installation of magnesium anodes, the potential around the tank rim was found to be —0.96 volt. This indicated over-protection since a structure is assumed protected if the potential is lowered to —0.85 volt. While the tank was empty a hole was cut in the center of the tank bottom and the potential was found to be —0.70 volt, which is inadequate for protection according to the —0.85 volt rule. In addition drops as great as several volts between rim and center have been observed on a water seal gas holder.[3] Thus the generally accepted rule does not always apply.

Because of these discordant results it was assumed that certain important factors for a proper solution of the problem were being neglected. It, therefore, seemed desirable to investigate the problem in the laboratory on small scaled models of tank bottoms to determine the difficulty and, if possible, to devise better methods for determining current requirements. The methods devised were then tried on a limited number of storage tanks in the field.

## II. Summary and Conclusions

Previously used methods for determining current requirements for cathodic protection of tank bottoms are more or less empirical and are not always satisfactory. The current density on the outer rim of the tank bottom is greater than that in the center and the current density is largely controlled by earth conditions under and adjacent to the tank bottom. Adequate protection to the tank rim does not insure protection to the center of the tank bottom. In addi-

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tion, as a result of the model studies, it was concluded that current potential curves were unsuitable for the determination of cathodic current requirements for tank bottoms.

By means of a theoretical analysis of the problem together with laboratory studies on a scaled model tank bottom employing a variety of simulated earth conditions, empirical relations were devised in which four terminal resistivity measurements are used to determine the efficiency of current distribution on tank bottoms. The efficiency of current distribution is defined as the ratio of current density at the tank bottom center to the average current density. In addition it was shown that the resistance of pads or coatings on tank bottoms can be estimated by this method. Thus by knowing the efficiency of current distribution and by independently determining the minimum current required for protection, a closer estimate of current requirements for cathodic protection of tank bottoms is obtained.

A limited number of tests were carried out on field tanks. Because of the warping of the tank bottoms due to load release, the agreement between calculated efficiency of current distribution from model-derived equations and actual measured values was not particularly good.

Because of the limited amount of field data, additional field evaluation is needed before the proposed methods can be recommended for general use.

## III. Statement of Problem

Whenever cathodic protection is applied to any structure the engineer must decide where to place one or more anodes and how much current must flow from the anodes through the earth or water to the structure. Even with the best possible arrangement of anodes it is usually impossible to apply exactly the amount of current needed to protect every part of a large structure. Hence it is necessary to overprotect certain surfaces in order to obtain sufficient current density on other surfaces.

On most structures it is possible to measure the potential of those surfaces where the current density is the least and thus determine the amount of current needed for protection. This method is applicable to pipe lines in which case the reference electrode is placed in contact with the soil over the pipe.

However, on some structures such as oil well casings the current density is least near the lower end of the casing. On tank bottoms the current density is least on the center of the bottom surface. It is very difficult to place reference electrodes at these locations. Thus current potential curves were obtained on well casings in the Loudon Pool in Illinois by placing the reference electrode at least 75 feet from the well head. The value of the protective current agreed roughly with the values estimated from IR drop measurements in the casing.[4] Since tank bottoms are similar to well casings in that the most remote part is the most difficult to protect, current potential curves are a possible means of estimating cathodic current requirements on tank bottoms.

The full advantage of cathodic protection on tank bottoms cannot be realized until the engineer is provided with a method of determining in a convenient manner the amount of protective current required to produce the necessary current density at the center of the tank bottom.

## IV. Theoretical Considerations

### 1. *General*

Certain techniques and principles useful in the investigation of tank bottoms have been assembled in this section. The use of the four-terminal resistivity measurement and the theory on which it is based, are discussed in relation to cathodic protection of tank bottoms. The current distribution on a tank bottom under certain simplified conditions is calculated.

### 2. *Four Terminal Resistivity Measurements*

#### a) Four Equally Spaced, Small, Hemispherical Electrodes

The four-terminal resistivity measurement is used to determine the apparent resistivity of the earth in the immediate vicinity of the tank bottom. The theory on which this is based is shown below.

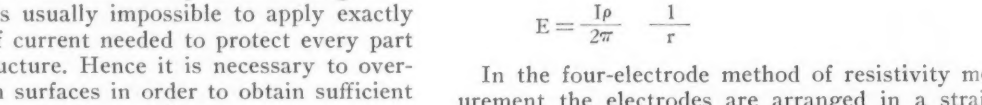
The potential difference E between two points at distances $r_1$ and $r_2$ from the center of a small spherical electrode discharging current I in a uniform medium of resistivity $\rho$ is

$$E = \int_{r_1}^{r_2} \frac{I\rho\, dr}{4\pi r^2} = -\frac{I\rho}{4\pi}\left(\frac{1}{r_2} - \frac{1}{r_1}\right) \quad (1$$

If the limits are chosen so that $E = O$ when $r_2 \rightarrow \infty$ and where the medium is changed to semi-infinite then

$$E = \frac{I\rho}{2\pi} \quad \frac{1}{r} \quad (2$$

In the four-electrode method of resistivity measurement the electrodes are arranged in a straight line with a distance $a$ between adjacent electrodes. The outer electrodes 1 and 4 are chosen as current electrodes and the inner electrodes 2 and 3 are the potential electrodes. This is illustrated below.




Then the potential difference between 2 and 3 produced by a positive current I at 1 and a negative current I at 4 is as follows:

$$E_{(2\text{-}3)} = \frac{I\rho}{2\pi a} - \frac{I\rho}{2\pi\,(2a)} - \left(\frac{I\rho}{2\pi\,(2a)} - \frac{I\rho}{2\pi\,a}\right) = \frac{I\rho}{2\pi}\left(\frac{1}{a} - \frac{1}{2a} - \frac{1}{2a} + \frac{1}{a}\right) = \frac{I\rho}{2\pi} \quad \frac{1}{a} \quad (3$$

Now the resistance

$$R_{(1\text{-}4)\ (2\text{-}3)} = \frac{E_{(2\text{-}3)}}{I_{(1\text{-}4)}} = \frac{\rho}{2\pi a} \quad \text{or} \quad \rho = 2\pi a R \quad (4$$

#### b) Disc and Three Small Hemispherical Electrodes

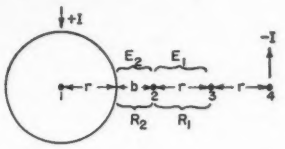
Similar to the development indicated in equation 2 it can be shown that the potential at a point located a

distance $a$ from the center of a conducting disc[5] of radius r and discharging a current I is:

$$E = \frac{I\rho}{2\pi} \quad \frac{1}{r} \quad \sin^{-1} \quad \frac{r}{a} \qquad (5$$

It should be noted that this relationship holds true only in the plane of the disc.

Now if a disc is substituted for one current electrode in the four-electrode method of resistivity measurement as schematically illustrated below.




Then the potential drop from the disc to electrode 2 can be expressed as follows.

$$E_2 = \frac{I\rho}{4r} - \frac{I\rho}{2\pi r}\sin^{-1}\left(\frac{r}{3r+b}\right) - \frac{I}{2\pi r}\sin^{-1}\left(\frac{r}{r+b}\right) + \frac{I\rho}{4\pi r} \qquad (6$$

Similarly the potential drop between electrodes 2 and 3 can be expressed as follows.

$$E_1 = \frac{I\rho}{2\pi}\left[\left(\frac{1}{r}\sin^{-1}\left(\frac{r}{r+b}\right) - \frac{1}{r}\sin^{-1}\left(\frac{r}{2r+b}\right) + \frac{1}{2r}\right)\right] \qquad (7$$

Now if b is so chosen so that $E_2 = E_1$ it is found that

$$b = 0.3225\,r \text{ and } R_1 = R_2 = \frac{0.91\,\rho}{2\pi r} \qquad (8$$

Equation 8 is applicable only for a semi-infinite medium of uniform resistivity.

### c) Discussion of Four-Terminal Resistivity Measurements in the Field

The relationships set forth in sections a) and b) above are valid only for the case of a medium of uniform resistivity. In general the resistivity of the earth varies from place to place on the surface and with depth. Usually the change in resistivity is greater in the vertical direction than in the horizontal. By means of equation (4 a definite value of resistivity of the earth can always be obtained for every electrode spacing. This is referred to as the "apparent resistivity" for this particular spacing or spread. It has been subject to considerable misinterpretation by corrosion engineers. It has often been assumed that when an apparent resistivity measurement is made with a span of eight feet, for example, the average resistivity of the earth is obtained to this depth. This, however, is not even approximately correct. For example,[6] if the earth to a depth of eight feet has a uniform resistivity of 1000 ohm centimeters and is underlain by an insulator, the apparent resistivity with an eight foot spread will be approximately 1500 ohm cm. If, on the other hand, a perfect conductor is substituted for the insulator, the apparent resistivity will be about 700 ohm cm. Hence, apparent resistivities could vary from 700 to 1500 ohm cm depending on the underlying material even though the actual resistivity to a depth of eight feet was 1000 ohm cm. However, more reliable methods exist for the measurement and interpretation of soil resistivities which will be discussed later in the report.

### 3. *Current Distribution on a Disc in a Uniform Medium*

One of the factors that must be considered in the cathodic protection of tank bottoms is the distribution of applied current over the surface of the tank bottom. For a tank bottom resting on a soil of uniform resistivity, where polarization is neglected, the current density at the center is one half the average current density.

The distribution of current on a disc in a medium of uniform resistivity is equivalent to the distribution of charge on a metallic disc in space. The capacity of a disc in free space is

$$C = \frac{2r}{\pi} \qquad (9$$

where C is the capacity of the disc in cgs electrostatic units and r is the radius of the disc in centimeters. The resistance of a disc to remote earth can be expressed as follows.

$$R = \frac{\rho}{4\pi C} = \frac{\rho}{8r} \qquad (10$$

where R is the resistance in ohms, $\rho$ the resistivity in ohm centimeters, and r in centimeters and C is in cgs electrostatic units. The surface charge density on the disc at a distance $a$ from the center is[7] as follows:

$$\delta = \frac{Q}{4\pi r\,(r^2 - a^2)^{1/2}} \qquad (11$$

where Q is the total charge on the disc and $\delta$ is the charge density.

When $r = a$, $\delta = \infty$, and when $a = 0$ $\delta = \frac{Q}{4\pi r^2}$

Since the average charge density is $\frac{Q}{2\pi r^2}$, then

$$\frac{\delta \text{ Center}}{\delta \text{ Average}} = \frac{\frac{Q}{4\pi r^2}}{\frac{Q}{2\pi r^2}} = 0.5 \qquad (12$$

Hence for a disc resting on a medium of uniform resistivity the current density at the center is one half the average current density, provided polarization is neglected.

### 4. *Discussion of Variations in Earth Resistivity and Coatings on Current Distribution on Tank Bottoms*

If all storage tanks rested on soils of uniform resistivity, in the absence of coatings on tank bottoms the only problem in the design of tank bottom protection would be the determination of the current density requirement for protection. For any tank the area of the tank bottom would be calculated; this area would be multiplied by the required current density for protection and the result would then be multiplied by two, since the efficiency under these conditions is 0.5. It should be appreciated that this situation is highly idealized.

Now if a thin layer of very high resistivity soil is adjacent to the tank bottom and the earth below is very low in resistivity, the current distribution on the tank bottom would be essentially uniform. In other words, the efficiency under these conditions will approach one. Conversely, if a thin layer of soil of low resistivity is adjacent to the tank bottom, underlain by soil of high resistivity, it would be virtually impossible to get current to the central portion of the tank bottom and thus the efficiency of current distribution would approach zero. It is evident that a coating of high resistivity would always improve current distribution on the tank bottom.

### 5. *Theoretical and Experimental Approach to Problem*

It is apparent from the foregoing that the distribution of applied current on an uncoated tank bottom is determined by the variation of soil resistivity under and in the vicinity of the tank bottom. In addition, high resistance coatings play a part and the above relationships are complex and not amenable to solution by simple mathematical methods. Hence current distribution studies were made on small model storage tanks in the laboratory to devise empirical methods for the determination of efficiency of current distribution and apparent resistivity of the earth as obtained by four terminal resistivity relationships.

## V. Description of Apparatus

### 1. *Dimensional Relationships*

The model was chosen to represent a tank bottom 100 feet in diameter, erected on soil of 500 ohm cm resistivity which corrodes at a rate such that the current density required for protection is 2 milliamperes/sq. ft. It was considered important in the case of the corroding model to have the potentials everywhere the same as on the prototype, insofar as possible, and to use current densities about equal to the protective current values. If these prerequisites are satisfied and a convenient linear dimensional ratio is chosen, it is seen from Table I that all other important dimensional ratios are fixed. With the model chosen as one foot in diameter, the resistivity of the electrolytic solution used was 5000 ohm cms under these conditions. The current density required to protect a copper-steel couple in the model tank solution of dilute potassium chloride was about 20 ma/sq ft.

**TABLE I—Dimensions of Tank Bottom Model**

| Dimension | Ratio Prototype/ Model | How Determined |
|---|---|---|
| 1. Length | 100 | Chosen |
| 2. Current Density | 0.1 | From ratio of protective values, i.e., 2 ma/sq. ft. / 20 ma/ sq. ft. |
| 3. Voltage | 1 | Chosen |
| 4. Area | $10^4$ | Fixed from (1) |
| 5. Current | $10^3$ | Fixed from product of (2) and (4)* |
| 6. Resistance | $10^{-3}$ | Fixed from (3) divided by (5) |
| 7. Resistivity of Medium | 0.1 | Fixed from $\frac{\text{Potential Gradient Ratio}}{\text{Current Density Ratio}} = \frac{1}{\frac{100}{0.1}} = 0.1$ |

* $I_m = i_m A_m$ and $I_p = i_p A_p$.

where,

$I$ = current

$i$ = current density

$A$ = area

Then,

$$\frac{I_p}{I_m} = \frac{i_p A_p}{i_m A_m} = \frac{i_p}{i_m} \frac{A_p}{A_m}$$

(Subscript m refers to model; p to prototype.)

The ratios defined in Table I fix the dimensions of the model itself. The problem of varying the efficiency of current distribution can readily be solved by placing the model in a tank, or container, so that it is just under the surface of the surrounding uniform medium, dilute potassium chloride solution. By changing the nature of the container bottom and the depth of the water, variations can be obtained in the efficiency of current distribution. For example, with this arrangement the efficiency will be very low if the water is shallow and the container bottom is made of Bakelite. Increasing the depth of water under the tank bottom will gradually increase the efficiency to 0.5. By replacing the insulating, (Bakelite) bottom with a conductor (copper) the efficiency can be changed to just above 0.5. Reducing the depth of water over the copper bottom will further increase the efficiency until it approaches 1.0. Hence, with these simple arrangements it is possible to obtain the complete range in efficiency with an applied current. With any chosen depth of water over either a copper or Bakelite bottom in the tank, it is possible to make four-terminal resistivity measurements and to obtain apparent resistivity-span curves. Such curves were obtained along with the current distribution efficiency measurements on a variety of conditions in the tank. In some of the experiments the copper bottom was replaced by agar.

Another important requirement of the model is that it should be possible to determine the corrosion rate at any time on any part of the model. To accomplish this, advantage was taken of a characteristic of the iron-copper couple. If an iron specimen in a corrosive solution is corroding at a certain rate and a part of the iron is replaced by copper, the rate of metal loss will remain the same but it will all occur on the remaining iron.[8] Hence, if the surface of the iron exposed is made relatively small with

respect to the copper surface the galvanic current is a measure of the corrosion rate.

Finally, the standard practice for spacing tanks is a rectangular pattern in which the distance between tanks centers is about three tank diameters; consequently, the one-foot diameter tank model was placed in the center of a Bakelite container which was three feet square. By considering the electrical images of the model in the sides of the Bakelite container it can be seen that the model represents a single tank in a tank farm of identical tanks and infinite extent. The auxiliary anode was a carbon rod placed along one side of the model tank. Measurements showed that the place of minimum current density remained close to the center of the model tank bottom and the efficiency of current distribution was independent of the anode position as long as the anode was 1½ diameters from the center of the model.

### 2. *Description of Apparatus*

All of the above requirements were embodied in the tank bottom model which is shown in Figure 1. It consists of a bronze screen through which thirty-one ⅛-inch steel rods, which serve as the anodes, project about 3/16-inch. The rods are covered with an insulating flexible spaghetti tubing except for the circular end surface which is exposed. The actual surface area of the screen was 1.107 square inch per square inch of screen. The anodes were symmetrically and uniformly arranged so that the area of the screen associated with each anode was the same. The area ratio of bronze to steel was 4.04 square inch per anode or 330 to one. A square portion of screen 4 sq. in. in area surrounding the central anode was isolated from the remainder of the model tank bottom so that the applied current density at the center could be measured. Such a large ratio of cathode to anode was not entirely ideal as a couple for cathodic protection potential tests since the galvanic current density on the cathode area was higher near the anodes. However, it was impracticable to incorporate a greater number of anodes in the corroding model.

To investigate the effects of pads, or coatings, under a tank, models were devised with a definite and fixed resistance per unit area. This was accomplished by drilling uniformly spaced holes in a circular Bakelite sheet and by attaching a rim so that current could flow to the model only through the holes. Figure 2 is a photograph of one of these model coatings.

### 3. *Description of Electrical Circuit*

A schematic diagram of the electrical circuit used with the model is shown in Figure 3. The current to the central anode, the central isolated screen, the central couple, and the remaining thirty anodes could be quickly measured by means of a circuit inserting switch S′ in positions 1, 2, 3, 4, etc., respectively. The resistance of the shunt was chosen so that the drop across it was always less than 400 microvolts, which is the full scale reading of the Brown self-balancing potentiometer. The arrangement for controlling and measuring the current in the circuit of the external anode is obvious from the figure. The micro-switch S, the potentiometer, and the calomel electrode were used to obtain current potential curves. Switch S was held in position 1 by a spring. When it is momentarily operated, the external anode circuit is opened and the calomel electrode and potentiometer are connected to the model.

On actual structures where the external anodes are much greater the switch S can be arranged to operate a Ford starter switch, or similar electrically operated switch of large current capacity.

## VI. Experimental Procedure

### 1. *Current Potential Curves on Models*

Current potential curves were obtained on the simplest possible structures in the model container. These were obtained on the following:

(a) A corroded steel wire arranged so that the applied current density was uniform over the entire surface.

(b) A bronze-steel couple having the same area ratio as a couple in the model tank bottom. A uniform current density was applied to the couple.

(c) Current potential curves were obtained on the tank bottom model and the galvanic current flow in the couples was observed at the same time. In these measurements the current distribution on the tank bottom was varied by changing the water level and height of the model over Bakelite, copper and agar bottoms in the Bakelite tank.

### 2. *Current Distribution Efficiency Measurements on the Tank Bottom Model*

Current distribution efficiency measurements were made over a wide range of applied current, with various depths of water over Bakelite, copper and agar bottoms in the Bakelite container. Similar measurements were also made with model coatings. It was found necessary to keep bubbles out of the holes and to have a small head on the water inside the "coating" in order to obtain reproducible results. Apparently the applied current heated the water sufficiently in the holes to change the resistance of the coating if circulation was not maintained.

### 3. *Resistivity Measurements in Model Tank*

Four-terminal resistivity measurements were made with both alternating and direct current. A potentiometer and two calomel electrodes were used on the potential measuring circuit for the direct current measurements. The alternating current measurements were made with a Biddle Ground Megger. In the model container the electrode spacing and, hence the electrodes, were small so the external resistance in the potential measuring circuit was not negligible. The resistances of the potential circuits of the Megger were measured for each position of the multiplying switch, the external resistance was obtained for each resistance measurement and an appropriate correction was applied to the Megger reading.

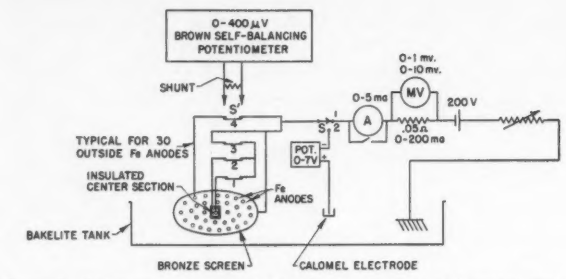



**Figure 3—Schematic diagram of electric circuits used with model tank. S—micro switch. S'—Circuit inserting switch, 33 positions (positions 1, 2, 3 and 4 shown). A—Weston Model 1. MV—Weston Model 622.**

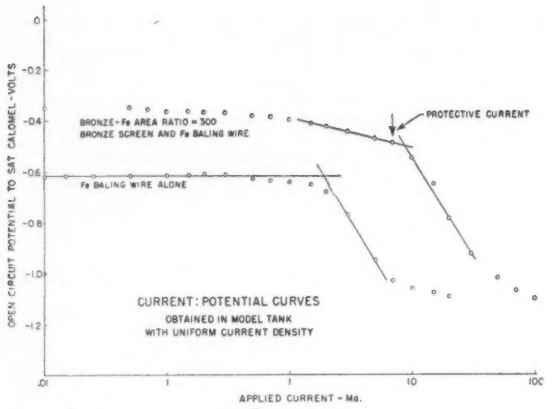

OPEN CIRCUIT POTENTIAL TO SAT CALOMEL - VOLTS
BRONZE - Fe AREA RATIO = 300
BRONZE SCREEN AND Fe BALING WIRE
PROTECTIVE CURRENT
Fe BALING WIRE ALONE
CURRENT: POTENTIAL CURVES
OBTAINED IN MODEL TANK
WITH UNIFORM CURRENT DENSITY
APPLIED CURRENT - Ma.

**Figure 4**

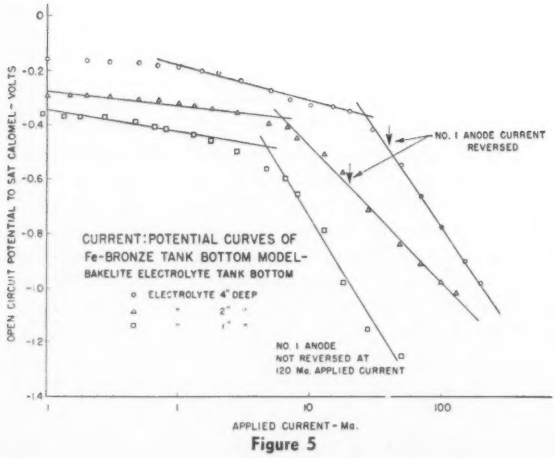

OPEN CIRCUIT POTENTIAL TO SAT CALOMEL - VOLTS
NO. 1 ANODE CURRENT REVERSED
CURRENT: POTENTIAL CURVES OF
Fe-BRONZE TANK BOTTOM MODEL-
BAKELITE ELECTROLYTE TANK BOTTOM
ELECTROLYTE 4" DEEP
NO. 1 ANODE
NOT REVERSED AT
120 Ma. APPLIED CURRENT
APPLIED CURRENT - Ma.

**Figure 5**

### 4. *Measurements on Storage Tanks in the Field*

Upon completion of the model work, measurements were made on three storage tanks in the field. These measurements included:

(a) Regular four-terminal resistivity measurements in which the distance between terminals was varied from one to 200 feet.

(b) Modified four-terminal resistivity measurements.

(c) Current potential curves.

(d) Current distribution efficiency measurements. These measurements were made by cutting out and isolating one or more areas of the tank bottom near the center. This was possible because the tanks were being dismantled.

## VII. Results of Experiments

### 1. *Current Potential Curves*

Two typical current-potential curves obtained with the laboratory model are shown in Figure 4. One is for a single corroded steel wire which extended along one side of the Bakelite container while the anode was a carbon rod extending along the opposite side. The second curve is for a steel-bronze couple which, with the exception of shape, duplicated as closely as possible the couple on the tank model. The reversal of current in the anodic element occurred close to the current at which there is a distinct change in slope.

Curves obtained with the tank bottom model using a Bakelite bottom and tank depths of 4, 2 and 1 inch are depicted in Figure 5. The point at which the current in the central anode of the model was reversed is indicated in each curve. It might be concluded that the method has possibilities from the position of these points on curves for the 4-inch and the 2-inch depths, although the points are not in correct places on either curve. None of the curves, however, have very distinct points of change of slope and for the one-inch water depth, the break in the curve is not even close to the actual current required for protection. Many other similar curves were obtained with the tank bottom model and as with the curves shown in Figure 5, the change in slope nearly always occurred at a current less than that required to reverse the current in the central anode of the model. There appeared to be no reliable relation between the current-potential curve and the current required for protection of the model. It was therefore concluded that current-potential curves were not suitable for estimating cathodic protection current requirements for tank bottoms.

### 2. *Current Distribution Efficiency Measurements on Models*

It was found that the decrease of galvanic current in the couples in the tank bottom model was not proportional to the magnitude of the applied current, so the distribution of the applied current could not be calculated readily by this means. A more direct method of measuring efficiency was used. This consisted in isolating the central bronze-steel couple as shown in Figure 1 so that the change in current flow of both the steel and bronze could be measured.

Since the current density is nearly uniform over the central portion of the tank bottom as shown by plotting equation (11, the current density over the isolated area at the center was assumed to be the current density at the center. The efficiency E is then given by

$$E = \frac{\Delta_{ic}}{A_c} \frac{A_t}{i_t} \qquad (13$$

where

$\Delta i_c$ is the change in current in the central couple produced by an applied current $i_t$. $A_c$ and $A_t$ are, respectively, the areas of the central couple and the entire model tank bottom.

Figure 6 is a plot of current density at the center of the model tank bottom plotted against the average current density for various depths of water and changes in the nature of the bottom of the model container. It can be seen that the efficiency of current distribution varies widely

i.e.,

$$\left(\frac{\text{Current density at tank bottom center}}{\text{Average current density}}\right)$$

and depends essentially on the depth of water (dilute electrolyte) and the nature of the bottom in the container. For example, it takes ten times as much current to protect the center of a tank over Bakelite at a depth of one inch as it does over copper at approximately the same depth. These extreme variations in resistivity of the medium under a tank bottom will probably never be encountered in the field, but if relations can be devised that are applicable in the extremes, they probably will be reliable.

The variation in efficiency as indicated in Figure 6 is not obvious from a consideration of equation (11 and the discussion in Section IV 3. If the tank bottom were small or the soil resistivity low, then polarization should have a pronounced effect and the current density over the tank bottom would be more nearly uniform. Figure 6 shows that polarization has but a minor influence on current distribution on large tank bottoms. The small arrows on the curves are the values of applied current and current density at the center that just reverses the current flow in the central anode in the model. Since the model is dimensionally correct, the applied currents are in the range that would be applied to a tank bottom.

The efficiencies as calculated from equation (13 are plotted against the applied current for various model arrangements. These data are presented in Figure 7. It can be seen that there is some variation in efficiency with applied current for each of the various model arrangements. The data are especially erratic at low current densities where galvanic potential differences on the model are not suppressed by the applied current. Difficulties in operating procedure undoubtedly played a part. Coatings gradually formed on the bronze screen and the anodes became coated with rust which reduced the corrosion rate and the protective current requirements.

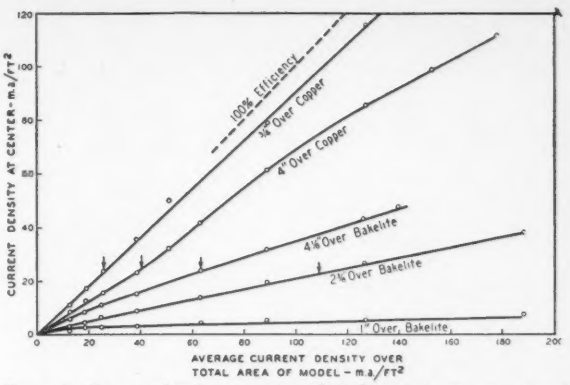

CURRENT DENSITY AT CENTER - ma/ft²
AVERAGE CURRENT DENSITY OVER TOTAL AREA OF MODEL - ma/ft²
100% Efficiency
¾" Over Copper
4" Over Copper
4¼" Over Bakelite
2¼" Over Bakelite
1" Over Bakelite

**Figure 6—Current density at center plotted against average current density for various model tank arrangements.**

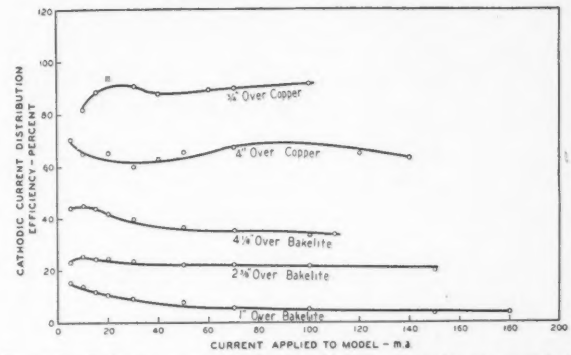



**Figure 7—Cathodic current distribution efficiency plotted against applied current for various model tank arrangements.**

This was corrected as much as possible by brushing the copper screen with dilute hydrochloric acid and by polishing the anodes with fine emery paper prior to taking measurements.

The current flow to the central anode nearly always drifted to a higher or lower value with time, so it was necessary to wait until this current became more or less stable, In addition, rapid circulation of water caused erratic behavior especially when large, applied currents were used. On the other hand, if circulation was not employed, currents were slow in reaching stable values.

Gentle circulation of the dilute electroylte appeared to offer the best means of obtaining reproducible results in a reasonable time. However, circulation was impossible with the agar bottom in the container since this would cause a rapid decrease in electrolyte resistivity. The value chosen for efficiency was usually the mean value over the higher current range and this nearly always included the protective value. It can be seen from Figure 6 that the slope or efficiency is nearly always constant over this range of applied current values.

### 3. *Resistivity Measurements and Efficiency of Current Distribution on Model Tank Bottom*

Presented in Table II are the data obtained on efficiency of current distribution and apparent resistivity measurements. The apparent resistivity meas-

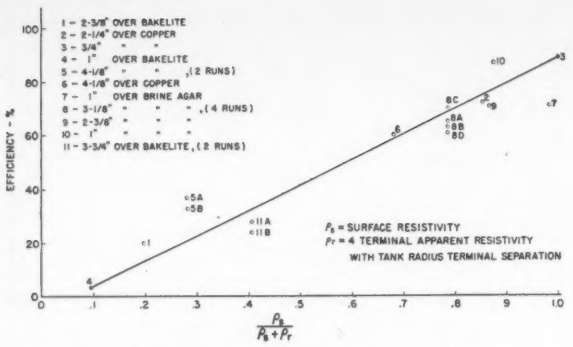

1 - 2-3/8" OVER BAKELITE
2 - 2-1/4" OVER COPPER
3 - 3/4" " "
4 - 1" OVER BAKELITE
5 - 4-1/8" " " ,(2 RUNS)
6 - 4-1/8" OVER COPPER
7 - 1" OVER BRINE AGAR
8 - 3-1/8" " " " ,(4 RUNS)
9 - 2-3/8" " " "
10 - 1" " " "
11 - 3-3/4" OVER BAKELITE, (2 RUNS)
EFFICIENCY - %
$\rho_s$ = SURFACE RESISTIVITY
$\rho_r$ = 4 TERMINAL APPARENT RESISTIVITY WITH TANK RADIUS TERMINAL SEPARATION
$\frac{\rho_s}{\rho_s+\rho_r}$

**Figure 8—Efficiency vs. resistivity factor $\frac{\rho_s}{\rho_s+\rho_r}$**

urements were obtained with both the standard and the modified four-terminal methods.

It was found that a satisfactory empirical relationship between apparent resistivity spread curves and corresponding efficiency of current distribution on the model tank bottom was given by the following expression:

$$E = \frac{\rho s}{\rho s + \rho r} - 0.1 \qquad (14$$

where

$\rho_s$ is the surface resistivity and this, in the model container, is the actual resistivity of the dilute electrolyte.

$\rho_r$ is the apparent resistivity with a span equal to the model tank bottom radius.

A plot of $\frac{\rho_s}{\rho_s + \rho_r}$ versus E is presented in Figure 8. Equation (14 is represented by the straight line in the figure.

It is apparent that the medium under the model tank bottom is composed of two layers of different resistivity and that this approach was used to simulate variations in earth conditions under storage tanks in the field.

This does not imply that all tanks are actually resting on formations which possess two layers of different resistivity. It does imply, however, that if the soil under the tank were replaced with an equivalent two-layer combination, the current flow and potential distribution under and around the tank bottom would be the same. It is recognized that this may be an oversimplification and that the resistivity curves obtained in actual practice may not fit any of the calculated two-layer curves. Bearing this in mind, a method is suggested for field use to estimate current efficiency distribution on tank bottoms. That is the estimation of the resistivity of the soil under the tank bottom by measurements taken near the tank. If the surface soil is reasonably moist and the apparent resistivity approaches a definite value as the span is reduced, the value obtained at the one foot or shortest span may be used. This will give $\rho_s$. $\rho_r$ is the apparent resistivity with a span equal to the tank radius. Then using the relation presented in Figure 8, an estimation of current efficiency is obtained.

This method described above has the following limitations:

a) It assumes the soil conditions near the tank where the measurements are made are the same as those underneath the tank.
b) It does not take into consideration the effects of pads, or coatings, under the tank.

The above limitations of the standard four-terminal resistivity method may be overcome by means of the modified four-terminal method in which the tank bottom is one terminal. The theory on which this method is based, and the positions of the electrodes are given in Section IV, 2(b). The resistance $R_1$ is the potential produced between electrodes 2 and 3 divided by the current applied between electrode 1 (the tank bottom) and electrode 4. Similarly $R_2$ is the potential produced between electrodes 1 and 2 divided by the current applied between the tank bottom and electrode 4.

The electrode spacings are chosen to make $R_1$ and $R_2$ equal in a uniform medium, in the absence of polarization and tank bottom coatings. The values of $R_1$ and $R_2$ are given by equation (8 which for convenience is restated below.

$$R_1 = R_2 = \frac{0.91\rho}{2\pi r} \qquad (8$$

Since actual soil resistivities vary with depth and coatings may be present on the tank bottom, $R_1$ and $R_2$ will in general be different. In this case a redefinition of $\rho_1$ and $\rho_2$ is necessary. This is done by solving (8 for $\rho_1$ and $\rho_2$ as follows:

$$\rho_1 = \frac{2\pi r R_1}{0.91} \qquad (15$$

$$\rho_2 = \frac{2\pi r R_2}{0.91} \qquad (16$$

**TABLE II**
**Efficiency and Apparent Resistivity Measurements (in Ohm-Feet) With No Coating Under Model**

| Depth, Inches | Substratum Material | E | $\rho_s$ | $\rho_r$ | $\frac{\rho_s}{\rho_s+\rho_r}$ | $\rho_1$ | $\rho_2$ | $\frac{\rho_2-\rho_1}{\rho_2+\rho_1}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | Bakelite | 0.03 | 164 | 1500 | 0.098 | 2100 | 980 | —0.365 |
| 2½ | Bakelite | 0.19 | 166 | 720 | 0.187 | 665 | 436 | —0.208 |
| 2⅝ | Bakelite | 0.20 | 157 | 590 | 0.21 | | | |
| 4 | Bakelite | 0.365 | 200 | 510 | 0.282 | 435 | 297 | —0.188 |
| 4⅛ | Bakelite | 0.325 | 166 | 350 | 0.322 | 476 | 335 | —0.143 |
| 4⅛ | Copper | 0.60 | 200 | 94 | 0.68 | 84 | 112 | +0.143 |
| 4 | Copper | 0.64 | 170 | 74 | 0.70 | | | |
| 3⅞ | Copper | 0.72 | | | | 68.3 | 92.2 | +0.145 |
| 2¼ | Copper | 0.72 | 145 | 25 | 0.854 | 28.3 | 76.2 | +0.458 |
| ¾ | Copper | 0.90 | 200 | 0.39 | 0.998 | 1.30 | 33.9 | +0.927 |
| 1 | Agar* | 0.71 | 140 | 2.2 | 0.985 | | | |
| 1 | Agar* | 0.87 | 130 | 19 | 0.873 | | | |
| 2⅜ | Agar* | 0.71 | 160 | 25 | 0.865 | | | |
| 3⅛ | Agar* | 0.65** | 160 | 44 | 0.785 | | | |

*Agar saturated with potassium chloride (KCl)—thickness one inch.
** Average of four measurements.

The symbols $\rho_1$ and $\rho_2$ always refer to the modified four-terminal measurements while $\rho_s$ and $\rho_r$ always refer to standard four-terminal measurements.

4. *Resistivity Measurements on Coated Tank Bottom Model*

Presented in Table III are the data obtained on efficiency and apparent resistivity measurements with coated tank bottom models. These data together with some of the results of Table II are plotted in Figure 9 where $\frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$ is plotted against the efficiency of current distribution. A clearly recognizible trend is evident. It should be noted that this relation is equally applicable whether a coating is present under the tank bottom or not. Consequently the relation presented in Figure 9 is more general than that presented in Figure 8 since the latter is invalid if a coating is present.

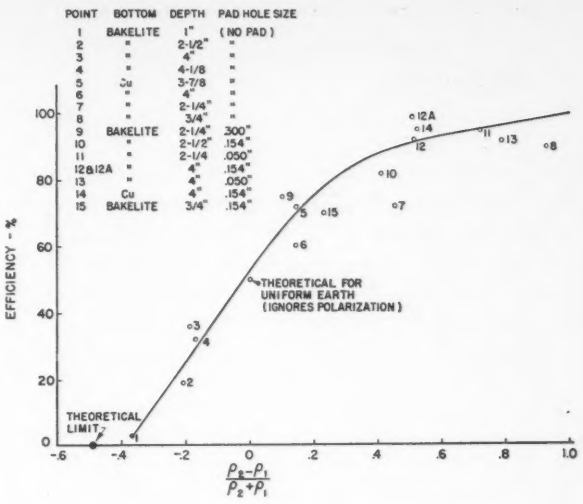

POINT BOTTOM DEPTH PAD HOLE SIZE
1 BAKELITE 1" (NO PAD)
2 " 2-1/2" "
3 " 4" "
4 " 4-1/8 "
5 Cu 3-7/8 "
6 " 4" "
7 " 2-1/4" "
8 " 3/4" "
9 BAKELITE 2-1/4" .300"
10 " 2-1/2" .154"
11 " 2-1/4 .050"
12&12A " 4" .154"
13 " 4" .050"
14 Cu 4" .154"
15 BAKELITE 3/4" .154"
EFFICIENCY - %
THEORETICAL FOR UNIFORM EARTH (IGNORES POLARIZATION)
THEORETICAL LIMIT
$\frac{\rho_s-\rho_1}{\rho_2+\rho_1}$

**Figure 9—Efficiency vs. $\frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$ for coated and uncoated tanks.**

If the modified four-terminal resistivity measurement is considered it can be seen that $\rho_1$ will be relatively unaffected by the presence or absence of a coating under the model tank. A comparison of values for $\rho_r$ and $\rho_1$ from Tables II and III reveals that these two resistivities are approximately equal for all simulated earth conditions under the model tank bottom. However, the value of $\rho_2$ will reflect the presence or absence of a coating under the tank bottom, whereas $\rho_1$ is a measure of the apparent resistivity of the soil. The difference between these two values would be an indication of the resistance of the pad or coating under the tank. By restating equation (8 in the following form

$$\rho_2 - \rho_1 = \frac{2\pi r}{0.91}(R_2 - R_1), \qquad (17$$

it can be seen that the difference in resistances; i.e., $(R_2 - R_1)$ would be a close approximation to the resistance of the coating provided this is sufficiently high. Examination of Table III shows that the agreement between coating resistance and $R_2 - R_1$ is reasonable when the coating resistance is 300 ohms or more. By referring to Table I it is seen that the coating on the model having a resistance of 300 ohms ($300 \times .7854 = 236$ ohms/ft.$^2$) corresponds to a coating on the prototype of $300 \times 10^{-3}$ or 0.3 ohms. This is equivalent to $0.3 \times 7854$ or 2360 ohms/ft.$^2$

5. *Determination of Current Density Requirements*

The method devised with the laboratory tank bottom model for determination of current distribution efficiency does not fix the current required to protect a tank bottom unless the current density for protection is known. In field practice the current density required for a particular tank installation may be estimated from past experience in the area, from corrosion rates, from measurement of current requirements on uncoated pipe lines, or test specimens in the immediate vicinity. Current-potential curves or the —0.85-volt rule may be used on any section of pipe line which has been under protection and on which the current density is known to be reasonably uniform.

**TABLE III**
**Efficiency and Apparent Resistivity Measurements in Ohm-Feet With Coatings Under Model**

| Depth, Inches | Substratum Material | Coating Resistance Ohms | E | $\rho_s$ | $\rho_r$ | $\rho_1$ | $\rho_2$ | $\frac{\rho_2-\rho_1}{\rho_2+\rho_1}$ | $R_2-R_1$ Ohms |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Bakelite | 300 | 0.70 | 164 | 1500 | 1780 | 2860 | 0.234 | 312 |
| 2¼ | Bakelite | 100 | 0.75 | ... | ... | 825 | 1020 | 0.106 | 56 |
| 2½ | Bakelite | 300 | 0.82 | 166 | 720 | 636 | 1520 | 0.410 | 256 |
| 2½ | Bakelite | 1000 | 0.95 | 166 | 720 | 640 | 3940 | 0.720 | 956 |
| 4 | Bakelite | 300 | 0.92 | 166 | 350 | 431 | 1345 | 0.515 | 265 |
| 4 | Bakelite | 300 | 0.99 | ... | ... | ... | ... | ... | ... |
| 4 | Bakelite | 1000 | 0.92 | 166 | 350 | 428 | 3730 | 0.795 | 956 |
| 4 | Copper | 300 | 0.95 | 170 | 74 | 69.4 | 920 | 0.526 | 246 |

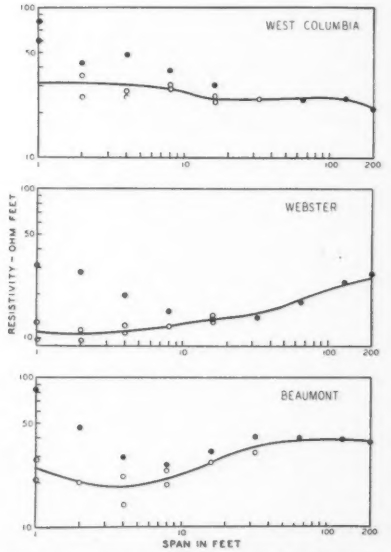



**Figure 10—Standard four-terminal resistivity-span curves obtained in field.**

### 6. *Field Measurements on Tank Bottoms*

#### a) Standard Four-Terminal Resistivity Measurements

The results of the standard four-terminal resistivity measurements made on storage tanks of the Humble Pipe Line Company in the vicinity of Houston, Texas, are shown in Figure 10. The data obtained are summarized in Table IV.

In order to obtain reliable resistivity data for the longer spans it was necessary to make measurements several hundred feet from the tank in locations free of pipe lines and other metallic structures. The resistivity data obtained in this way is shown by solid dots in Figure 10. The surface resistivity was measured with shorter spans near the tanks. This was done because grading operations prior to tank construction removed most of the surface soil. The results of these measurements are shown with circled points. The single curve for each tank was drawn so as to average the short span measurements near the tank and to gradually grade into the points for the longer spans. Values of $\rho_s$ and $\rho_r$ were taken from the curve in each case. The tanks all have a diameter of 114 feet 6 inches so in each case $\rho_r$ is for a span of 57 feet.

The curves for West Columbia and Webster can be fitted to calculated two-layer curves. The resistivity of each layer $\rho_a$ and $\rho_b$ and the thickness, d, of the top layer can then be determined. These data are also shown in Table IV. The curve for Beaumont appears to show a minimum, so it was fitted to a calculated three-layer curve. The three resistivities and the two depths are also given.

#### b) Modified Four-Terminal Resistivity Measurements

The results of the modified four-terminal resistivity measurements in which the tank bottom is one terminal are given in Table V.

Two resistivity measurements with different applied currents were made in each location and measurements were made at two locations at each tank.

The results are presented in detail to show

1) That agreement between measurements at the same location is usually better than agreement between locations. Hence the differences are caused by actual variations around the tank and are not primarily due to errors in measurement.
2) There is clearly a difference in apparent resistivity and the efficiency of current distribution although all tanks are in the same general area.

#### c) Comparison of Observed and Calculated Efficiencies

A comparison of calculated and observed current distribution efficiencies in the field tests is given in Table VI.

The principal cause of wide variations in the efficiency measurements is believed to be warping of plates in the tank bottom which took place when the tank was emptied. The current flow to or from the isolated plate, for example, was changed whenever anyone walked near it. Definite values for efficiency, which were practically independent of the applied current, could be obtained in two tanks but the measurements at Webster seemed to be entirely erratic. The results at West Columbia could not be repeated on different days. The measurements of efficiency are at best rough approximations and are not reliable for the reasons noted above.

The efficiencies calculated from the resistivity spread curve and from resistivity measurements using the tank bottom as one terminal arrange the three tanks in the same order. The calculated efficiencies do not agree as closely as might be expected although it is possible that all the measured resistivities are within about 10 percent of their correct values. The lack of agreement in the calculated re-

**TABLE IV**

**Summary of Standard Four-Terminal Resistivity Measurements in the Field (in Ohm Feet)**

| Location | $\rho_s$ | $\rho_r$ | $\rho_a$ | $\rho_b$ | $\frac{d}{\text{Feet}}$ | $\frac{\rho_s}{\rho_s+\rho_r} - 0.10 = E$ |
|---|---|---|---|---|---|---|
| West Columbia. | 30 —35 | 28.8 | 30 | 24 | 10 | 0.46—0.49 |
| Webster..... | 9.5—12 | 17 | 13 | 20 | 40 | 0.26—0.31 |
| Beaumont..... | 20 —24 | 38 | (Three Layer) | | | 0.24—0.29 |
| | | $\rho_a$=30 $\rho_b$=10 $\rho_c$=45 $d_a$=1.6 ft. $d_b$=3.2 ft. | | | | |

**TABLE VI**

**Comparison of Observed With Calculated Efficiencies**

| Tank Location | Observed Efficiency | Calculated Efficiency (Fig. 8) | Calculated Efficiency (Fig. 9) |
|---|---|---|---|
| West Columbia... | 0.45 to 0.82<br>Best Values 0.60 | 0.46 to 0.49 | 0.67 to 0.73 |
| Webster..... | No satisfactory results | 0.26 to 0.31 | 0.20 to 0.39 |
| Beaumont..... | 0.44 to 0.46 | 0.24 to 0.29 | 0.03 to 0.16 |

**TABLE V—Field Resistivity Measurements Using Modified Method With Tank Bottom As One Terminal**

| | WEST COLUMBIA | | | | WEBSTER | | | | BEAUMONT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\rho_1$ | $\rho_2$ | $\frac{\rho_2-\rho_1}{\rho_2+\rho_1}$ | E | $\rho_1$ | $\rho_2$ | $\frac{\rho_2-\rho_1}{\rho_2+\rho_1}$ | E | $\rho_1$ | $\rho_2$ | $\frac{\rho_2-\rho_1}{\rho_2+\rho_1}$ | E |
| Location 1..... | 27.2 | 34.2 | +0.115 | 0.67 | 15.8 | 11.8 | —0.145 | 0.33 | 41.5 | 19.4 | — 0.37 | 0.03 |
| | 27.4 | 35.5 | +0.127 | 0.68 | 15.7 | 12.9 | —0.098 | 0.39 | 43.6 | 21.7 | — 0.33 | 0.08 |
| Location 2..... | 24.8 | 35.2 | +0.177 | 0.73 | 18.2 | 11.3 | —0.234 | 0.20 | 36.0 | 20.6 | — 0.27 | 0.16 |
| | 25.2 | 31.8 | +0.118 | 0.69 | 18.3 | 13.3 | —0.158 | 0.31 | 36.1 | 19.8 | — 0.29 | 0.13 |
| Average..... | 26.2 | 34.2 | +0.132 | 0.69 | 17.0 | 12.3 | —0.161 | 0.30 | 39.4 | 20.4 | — 0.32 | 0.10 |

sults might be accounted for in several ways such as:

1) Differences in resistivities between the soil immediately under the tank and the surface soil near the tank.
2) The span to use for $\rho_r$ was arbitrarily selected on the basis of model measurements. The span would be very critical at Beaumont where a low resistivity layer exists between 1.6 and 3.2 feet, less critical at West Columbia and still less at Webster.
3) It may be that the method which was worked out with a two-layer model will not apply to a three-layer or more complicated earth.

### d) Current-Potential Curves

Current-potential curves were made on all three tanks with reference electrodes in various positions around the tanks and under the isolated test plates near the center of the bottoms. In all cases it was possible to obtain curves having reasonably definite points of change in slope and the changes in slope occurred at reasonable values for the required protective current. In two cases the electrode under the test plate indicated a greater current at the change in slope than the electrode around the tank.

### 7. *General Discussion of Method*

It is believed that the methods presented in the foregoing are a reasonable approach to the problem of estimating cathodic current requirements for tank bottom protection. However, the erratic and limited results to date are such that the methods require further study before they can be recommended for general field use. It is also believed that more satisfactory results can be obtained by installing isolated plates under the tank bottom, thus permitting measurements to be made when the tank is full. Plates could be installed at the time the tank is erected or when it is being repaired. A well-insulated wire connected to the plate and extending to the outer edge of the tank would permit measurements of efficiency to be made at any time with various applied currents.

## X. Acknowledgments

The authors express their appreciation to the management of the Carter Oil Company and the Standard Oil Development Company for permission to publish this paper. They are also indebted to the Humble Pipe Line Company for assistance in making field measurements.

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## DISCUSSION

**Question by S. J. Artese, Shell Oil Company, Wilmington, Cal.:**

With rectifier and anodes on one side of tank and finding a protective potential on the other side, why is the tank not protected?

**Reply by S. P. Ewing:**

If the anode is removed at least one tank diameter from the nearest part of the tank, current flows away from the anode in all directions and flows toward the tank bottom from all directions. With the anode at this distance there was no noticeable difference in the current density around the edge of the model tank bottom, but the current density always dropped off toward the center.

Assuming that the potential of the remote side of the tank is a reliable indication of protection is equivalent to assuming that the current density is a minimum near the remote edge, or it is equivalent to assuming that the distance to the anode is the principal factor affecting current density over the tank bottom. The measurements described on the model indicate that this factor has no noticeable influence on current distribution. Of course, when the anode is placed near the tank, the current distribution would not be symmetrical and the problem is more complicated.

# Effects of Polarization on Telephone Cable Buried Through a Salt Bed ★

By DANIEL R. WERNER

THIS ARTICLE tells how the telephone company solved a cathodic protection problem affecting an important toll cable in Texas. The cable has an outer jacket of copper over the usual lead sheath which is insulated from the sheath by two layers of thermoplastic compound. The corrosion problem, therefore, deals with currents on the copper jacket. This of course differs from most telephone company corrosion problems which involve lead cable. The problem is of interest to cathodic protection engineers because the polarization effects in a salt layer are very large and may result in some unusual effects.

When current was drained from the copper jacket, the copper jacket to earth potential increased as the drain point was approached as would be expected. The current flow on the copper jacket, however, did not behave similarly and tests indicated a current loss when current flow test points on the copper jacket were placed sufficiently close together.

The toll cable with which this paper is concerned is known as the Dallas-El Paso "A" cable and the salt bed through which the cable was plowed is about 88 miles due east of El Paso, Texas, along the south side of United States Highway 62. The selection of this route through the salt bed area could not be avoided because of the rugged country and the necessity of having a road available for maintenance reasons. Figure 1 shows the extent of the salt lake bed area and the relative location of pipe lines owned by two pipe line companies with respect to the cable. The earth resistivity in the lake bed area to a depth of approximately 20 feet measured fairly uniform at a value of about 20 centimeter-ohms whereas the earth resistivity on the adjacent banks either side of the lake bed to the same depth measured from 500 to 1500 centimeter-ohms. The variation in the earth resistivity along the cable route through the salt lake bed area and for some distance either side to a depth of five feet is shown in Figure 2.

There were two pipe lines in service along this route at the time the cable was placed in 1947. Cathodic protection was in service for the protection of structures of both pipe line companies. The installation on Pipe Line No. 1 consisted of a wind driven generator located near the west edge of the large salt lake bed with its anode located directly under a trestle on which the pipe crossed the lake bed. The installation on the Pipe Line No. 2 group (at the time containing only two pipes) consisted of a gas engine driven generator with the anode placed approximately 100 feet north of the pipe lines which are buried in the lake bed. Approximately three years ago the generator on the Pipe Line No. 2 group was replaced with a rectifier and the associated made ground moved to its present location. At about the same time the wind driven generator on Pipe Line No. 1 was replaced with a gas engine driven generator and relocated to the drainage location about 94 feet north of Marker 22. About one year ago the gas engine driven generator on Pipe Line No. 1 at Marker 22 was also replaced with a rectifier. An equalizing bond was also connected between the two pipe lines opposite the rectifier on the Pipe Line No. 2 group to avoid interference currents between the structures of the two pipe line companies.

It was realized at the time the cable was placed that special measures would be required to insure adequate protection and joint investigations were conducted by representatives of the pipe lines and the telephone company in an effort to coordinate the protective installations. Pending the replacement of the wind and gas driven generators on the pipe lines temporary protection in the form of driven ground

**DANIEL R. WERNER is in charge of cable corrosion control engineering, Western Area, American Telephone and Telegraph Company, Kansas City, Missouri. Has been in electrolysis work on telephone cables since 1934. He is an engineering graduate of Rose Polytechnic Institute, Terre Haute, Indiana.**

## Abstract

Cathodic protection has been applied to a copper jacketed cable in a salt lake bed about one mile wide in which the earth resistivity was apparently uniform at about 20 ohm-centimeters. Current of about one ampere flowed on the copper jacket into the low earth resistivity lake bed area from the higher earth resistivity areas on either side and was found to be sustained by polarization effects when the cathodic protection current was removed. The current loss on the copper jacket was found to be concentrated in an area about 720 feet wide, 360 feet each side of the point where the cathodic protection current had been drained from the copper jacket. The copper jacket to soil potential tested most negative to a copper sulfate half cell in the 720-foot area where the current loss was concentrated and was of the order of —1.0 to —1.1 volts. Permanent remedial measures will consist of installations of magnesium anodes distributed throughout the low earth resistivity area and insulating joints in the copper jacket at locations where large changes in the earth resistivity occur.

★ A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

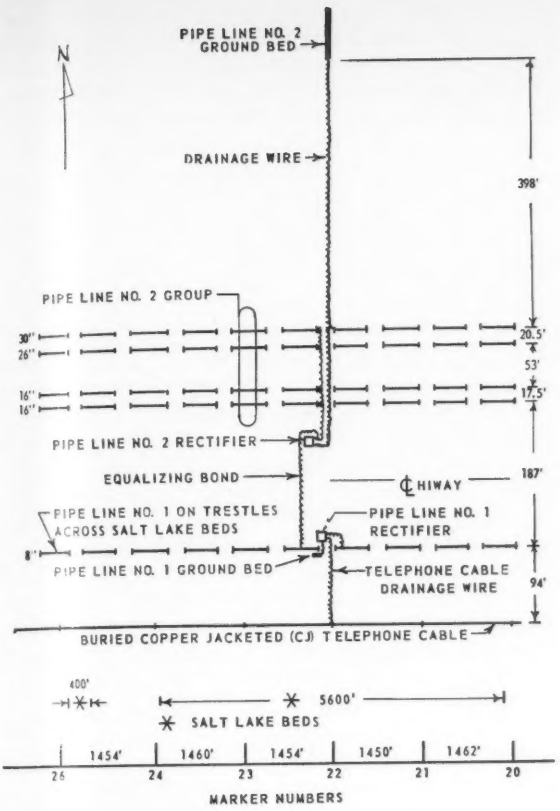


Figure 1—Proximity of the various pipe lines and telephone cable through the salt lake beds along U. S. Highway 62.

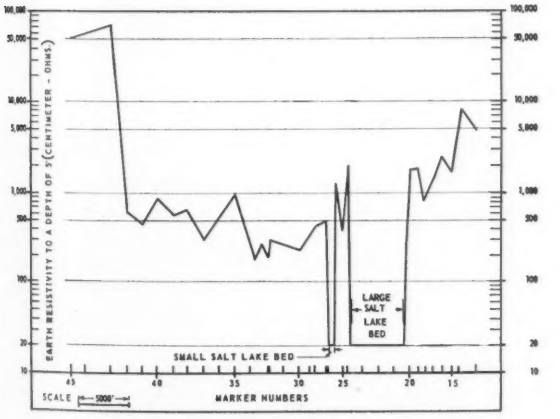


Figure 2—Extreme changes in earth resistivity to a depth of penetration of five feet is indicated.

rods was utilized for the cable. The galvanic potential difference between the copper jacket and the four 5-foot steel ground rods driven into the salt lake bed about 10 feet from the cable caused a current of about one ampere to flow from the copper jacket to the ground rods.

Further measurements made with the pipe line rectifiers turned off and on showed that the copper jacket of the telephone cable was receiving current

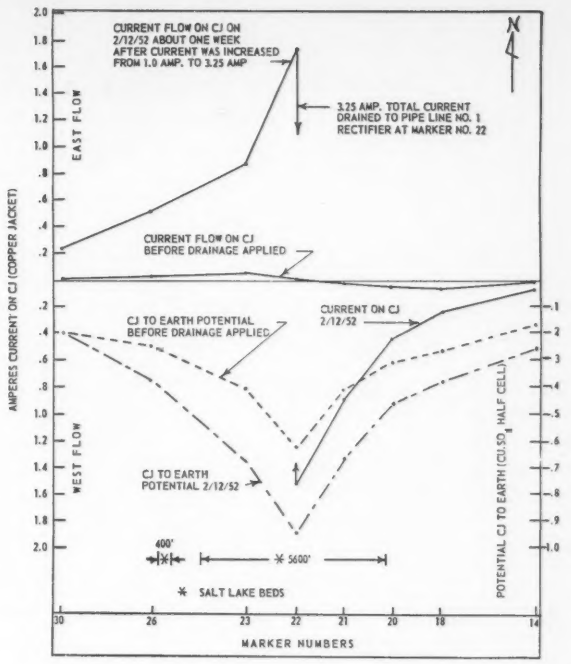
CURRENT FLOW ON CJ ON 2/12/52 ABOUT ONE WEEK AFTER CURRENT WAS INCREASED FROM 1.0 AMP. TO 3.25 AMP
3.25 AMP. TOTAL CURRENT DRAINED TO PIPE LINE NO. 1 RECTIFIER AT MARKER NO. 22
EAST FLOW
CURRENT FLOW ON CJ BEFORE DRAINAGE APPLIED
CJ TO EARTH POTENTIAL BEFORE DRAINAGE APPLIED
CURRENT ON CJ 2/12/52
CJ TO EARTH POTENTIAL 2/12/52
WEST FLOW
AMPERES CURRENT ON CJ (COPPER JACKET)
POTENTIAL CJ TO EARTH (CUSO4 HALF CELL)
400'
5600'
SALT LAKE BEDS
MARKER NUMBERS

Figure 3—The copper jacket to earth potential and the current flow on the copper jacket on 2/12/52 behave as might be expected with current drained from the copper jacket at Marker 22.

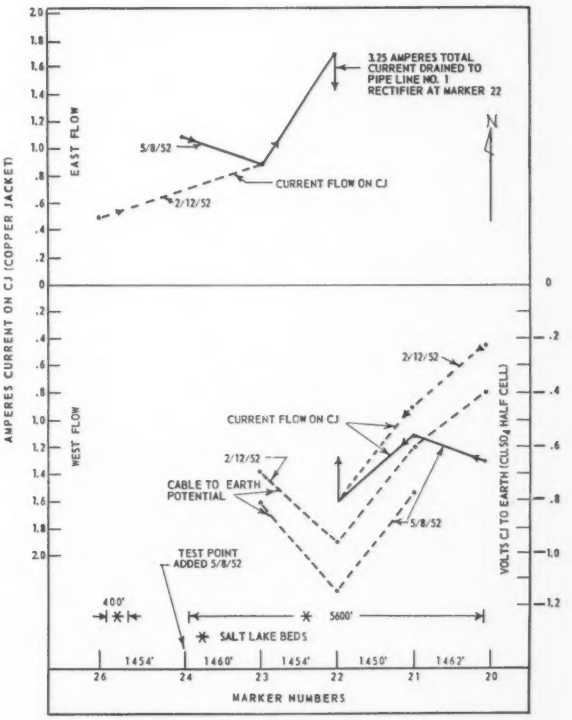


Figure 4—After 3.25 amperes had been drained for some time, a current loss from the copper jacket resulted due to polarization effects (solid curve).

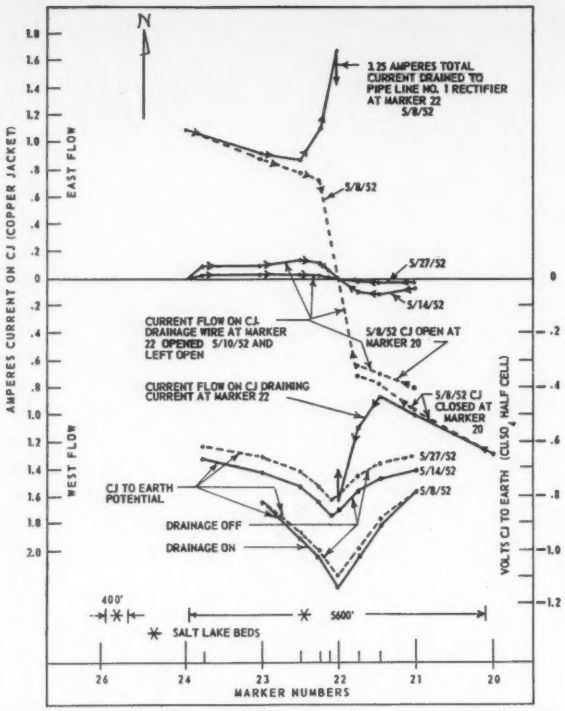


**Figure 5—Installation of additional current flow test points on either side of the drain point Marker 22 indicated a current loss from the copper jacket up to about 725 feet each side of the drain point (solid current curves).**

from the ground bed of Pipe Line No. 1 rectifier 94 feet north of Marker 22 and that this current flowed west along the cable from the vicinity of this marker. It was, of course, immediately recognized that where this current left the copper jacket and returned to the earth, corrosion of the telephone cable would occur. Therefore, with the cooperation of the pipe line people, a small amount of cathodic protection was applied to the telephone cable by connecting a resistance bond between the copper jacket at Marker 22 and the rectifier on Pipe Line No. 1. In 1951 the drainage current was first set at one ampere and initial tests showed an increase in the flow of current on the copper jacket as the drain point Marker 22 was approached. One year later, tests indicated that conditions had changed and that while current was still flowing on the copper jacket toward the drain point Marker 22, there was an actual loss of current from the copper jacket in the large salt lake bed. The amount of resistance in the bond at Marker 22 was, therefore, reduced and the drainage current increased to 3.25 amperes.

The two solid curves of Figure 3 show the current flowing on the copper jacket with both pipe line rectifiers energized under two conditions,

1) before any drainage had been applied to the cable and
2) after the drainage current to the Pipe Line No. 1 rectifier had been increased to 3.25 amperes.

The solid current curve close to the zero axis (condition 1) shows current on the copper jacket flowing from both directions toward Marker 22 then to earth. It would appear that this direction of current flow is in contradiction to the statement previously made that current flowed away from Marker 22 on the copper jacket. Actually the solid current curve is the resultant of two opposing currents, the larger current being that due to polarization at the surface of the copper jacket caused by the raised earth potential around the ground bed opposite Marker 22. The solid curve at the top of Figure 3 (condition 2) shows 1.75 amperes flowing to the drainage point from the west and the solid curve below the axis shows 1.5 amperes flowing to the drainage point from the east making a total of 3.25 amperes.

In May 1952, three months later, an investigation was made to determine why the drainage current had to be increased to 3.25 amperes at Marker 22. The solid lines of Figure 4 show the current flow on the copper jacket as found in May. Between Markers 20 and 21 a current loss from the copper jacket was indicated. An additional current test point was then added at Marker 24 and tests then indicated a current loss from the copper jacket, between Markers 24 and 23. For comparison the current flow on the copper jacket about three months previously just after the drainage current had been increased to 3.25 amperes is shown by dashed lines on Figure 4.

An effort was next made to obtain more definite information as to the actual area over which the current was being lost from the copper jacket. Additional current flow test points were installed on the copper jacket each side of Marker 22 as follows:

First, test points were placed half way between Markers 21 and 22 and half way between Markers 22 and 23. This placed the test points approximately 720 feet each side of Marker 22.

Second, test points were placed about 360 feet each side of Marker 22 splitting in half approximately the distance the first test points were placed each side of Marker 22, and

Third, one test point was placed about 180 feet to the left of Marker 22.

An additional current flow test point was also installed about 360 feet to the right of Marker 24. The continuity of the copper jacket at Marker 20 and Marker 24 was also broken as it was desired to prevent current from the higher earth resistivity areas each side of the salt lake bed from flowing into the low earth resistivity lake bed area.

The following tests were next made and the result plotted in Figure 5:

1. Current flow on the copper jacket and copper jacket to earth potentials with the drainage wire from Marker 22 to the Pipe Line No. 1 rectifier open and closed. Tests made May 8th with the copper jacket continuous at Markers 20 and 24.

**Result.** The copper jacket to earth potential changed from about 1.15 volts to about 1.1 volts at the drainage point, Marker 22, and changed negligibly at Markers 21 and 23 approximately 1450 feet each side of the drainage point. The current flow on the jacket materially changed in the area between Markers 21 and 23, the current being reduced from 1.68 amperes

east flow at Marker 22 to approximately zero. At Markers 21 and 23 about 1450 feet each side of the drainage point the current flow on the copper jacket was reduced about five precent to values of 1.00 and 0.85 amperes from original values of 1.05 and 0.90 amperes.

2. With the drainage wire open at Marker 22, the continuity of the copper jacket was broken at Marker 20 but left continuous at Marker 24. Current flow on the copper jacket and copper jacket to earth potential tests were then made between the test points Marker 21 to 22 inclusive. Tests made May 8th.

**Results.** The current still remained approximately zero at Marker 22 and was reduced less than about 12 percent at Marker 21 and the two adjacent test points to the left. This indicated that the current was being picked up from the salt lake bed in the area between Markers 20 and 21 and discharged in the salt lake bed between Markers 21 and 22. The current flow from one area to another was caused by the different values of polarization potentials existing on the surface of the copper jacket. The current flow on the copper jacket was being sustained because of the slow rate of decay of the polarization potentials.

3. With the continuity of the copper jacket broken at both Markers 20 and 24 (these markers are on the opposite banks of the large salt lake bed), measurements were made of current flow on the copper jacket and the copper jacket to earth potentials on May 14 and May 27, 4 days and 17 days respectively after the drainage wire from Marker 22 to the Pipe Line No. 1 rectifier was opened and left open on May 10th.

**Result.** The currents flow on the copper jacket gradually decayed in the large salt lake bed Markers 21 to 24 and after 17 days was down to a value of about 0.04 amperes from an initial value of the order of 0.8 ampere. The copper jacket to earth potential decreased but had not yet reached the potentials which obtained before the initial drainage current of one ampere was applied.

The results of test No. 1 showed a very high attenuation of the current drained from the copper jacket. Figure 6 shows how the current is attenuated. This curve was obtained by taking the difference between current flow measurements on the copper jacket with the drainage current from Marker 22 to the Pipe Line No. 1 rectifier off and on. The interval of time between readings and from the time the tests were started and ended was short as compared to the time required for polarization to increase or decay so that the polarization effects can be ignored.

The circuit used in the measurement of current flow on the copper jacket is shown in Figure 7 and the manner of using it is covered in Appendix A.

## Conclusions

The tests indicated the high degree of polarization which is experienced in a salt lake bed area and clearly point out that cathodic protection can rather quickly lose its effectiveness because of this

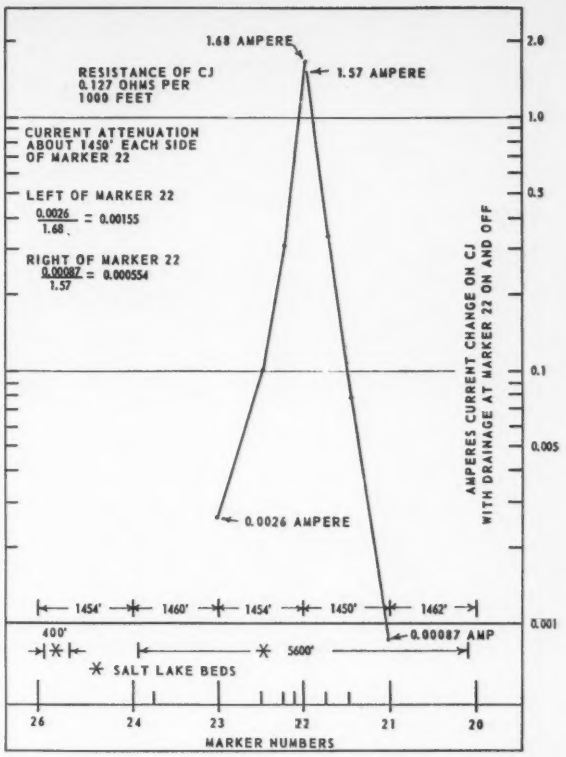


**Figure 6—Curve showing the high current attenuation along the copper jacket.**

polarization. Our analysis is that polarization can be set up on the copper jacket by two types of applied potentials:

1. Raising the potential of the environment. This effect was obtained in this case from the current drained from Pipe Line No. 1 which was forced into a made ground in the lake bed 94 feet from the cable.

2. Draining current from the copper jacket making it more negative to earth. The magnitude of the polarization potentials set up depend upon a) the magnitude of the current and b) the length of time which it is applied.

Under condition 2 above, when current is drained from the copper jacket over a long period of time, the polarization effects gradually creep out farther and farther away from the drainage point, increasing the current flow into the area polarized, from the adjacent unpolarized sections. A balance is ultimately reached between the polarizing effect of the drainage current and the depolarizing effect of the current flowing in from the adjacent unpolarized sections. The slope of the solid current flow lines on Figure 5 indicates there is an appreciable current loss between Marker 20 and a point half way between Markers 21 and 22 and between Marker 24 and a point half way between Markers 22 and 23. Where there is a current loss it is known that corrosion of the copper jacket will occur. An opportunity to inspect the copper jacket was had when the additional current flow test leads were installed. At this time a very slight and rather uniform corrosion of the copper was evident.

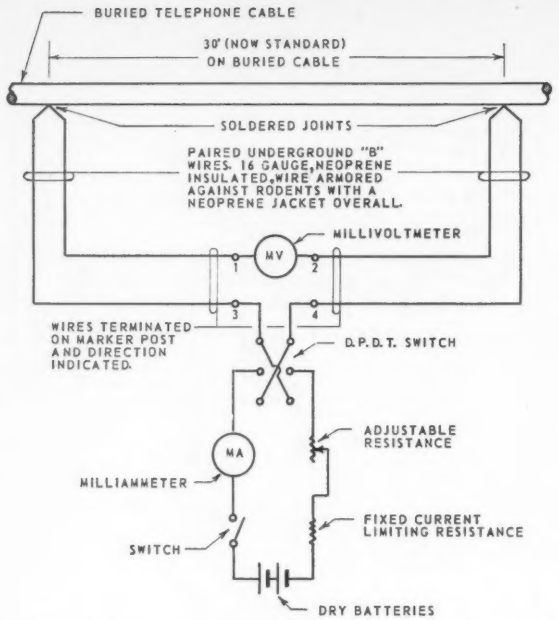


**Figure 7—Test circuit used for measuring current flow on buried telephone cables.**

From the above discussion it is obvious that additional drainage points must be established if the extreme amount of polarization is to be overcome. Either a distributed drainage wire or a number of magnesium anodes would be applicable and a cost study has indicated the later to be more economical. It is, therefore, planned to use magnesium anodes at about 360-foot spacing throughout the lake bed area, draining about 0.1 ampere at each such location, together with a drainage connection to Pipe Line No. 1 rectifier at Marker 22 adjusted for about 0.1 ampere. There is reason to believe this type of cathodic protection will provide adequate defense against corrosion in the salt bed.

## APPENDIX A

### Methods Used in Measurement of Current Flow on Telephone Cables Using Circuit of Figure 7.

Methods outlined herein may be applied on any structure with the substitution of suitable meters and other circuit constants for measuring the magnitude of the currents being handled. Test leads are shown bridged across 30 feet of cable. This length of sheath has been found from experience to be the best practical length for use on telephone cables and permits the use of a one millivolt full scale meter movement. Sheath currents of the order of one or two milliamperes can be measured readily.

Paired test leads are brought up to a marker post from each end of the 30-foot section. The two wires of the pair are soldered to the sheath at each end of the 30-foot section. Probably some error is incurred due to end effects because the two wires of the pair are soldered at one point on the sheath, however, considering the small currents involved, the small magnitude of the error and the economy of soldering both wires at one point, this method has been adopted as the most practical.

*Method 1—Null Method*

Knowing the resistance of the test leads or the cable sheath is not required for accurate measurements. This method is the fastest, easiest to use and does not require highly trained personnel. It may be difficult to use where the current flow on the sheath is changing rapidly. The circuit is shown in Figure 7. With the battery circuit closed, the current through the milliameter is varied by means of the adjustable resistance and the current applied to the cable poled by the DPDT switch to make the millivoltmeter read zero. The current read on the milliameter when the millivoltmeter reads zero is the current flowing on the cable sheath. The direction of the current flow must be determined from the marking on the test leads.

*Method 2—Ratio Method*

Knowing the resistance of the test leads and the cable sheath is not required but the scale of the millivoltmeter must not be changed for the most accurate measurements. The circuit is shown in Figure 7. With the millivoltmeter set on the scale on which the millivolt drop along the cable will be read, close the battery circuit and adjust the milliameter to 50 milliamperes and read the millivoltmeter. Switch the DPDT switch (the current should stay at 50 milliamperes) and read the millivoltmeter again. A current change of 100 milliamperes is thus caused to flow on the cable sheath and the corresponding millivolt change on the cable will be the algebraic difference of the two millivoltmeter readings. Calculate.

$$\text{Millivolts per Milliampere} = \frac{\text{Millivolts change}}{100} = 0.01 \times \text{Millivolts change} \qquad 1)$$

Next read the millivolts drop along the cable sheath with the battery circuit open and divide this reading by the factor obtained in 1). The result is the milliamperes of current flow on the cable sheath.

The voltage of the dry batteries must be at least 100 times the voltage drop along the cable for an accurracy of at least one percent. The large amount of resistance required in the battery circuit to limit the current will result in a steady milliameter reading even with a varying millivolt drop along the cable sheath.

*Method 3—Ohm's Law Method*

The resistance of the test leads and the cable sheath must be known. The resistance of the cable sheath may be obtained from prepared tables. The resistance of the cable sheath and the resistance of the test leads may be measured by using certain variations of the circuit of Figure 7. The methods will not be given here as they are well known among engineers. It will suffice to say that the three above methods have been found to give practically the same results from measurements made at many test points. The ease with which methods 1 and 2 can be used makes them particularly desirable for use by non-technical personnel on routine measurements.

# Effect of Composition of Steel On the Performance of Organic Coatings In Atmospheric Exposure*

*By F. L. LaQUE*
*and*
*JAMES A. BOYLAN*

THE STUDY to be described here was directed towards the possibility of reducing corrosion of automobile bodies by the use of steels containing alloying elements added to improve resistance to atmospheric corrosion. It became necessary to discover the extent to which the more corrosion resistant steels would demonstrate an advantage when painted or whether the protective value of the coating would be about the same on all steels.

In studying the effects of pigments in paints Nelson[1] concluded that an improvement in the corrosion resistance of steel had a beneficial effect on the durability of the paint coatings which showed up in better adherence of the paint and less pitting of the steel, which facilitated repainting.

Britton and Evans[2] also reported that the advantages of copper steel and wrought iron over ordinary steel were maintained when all were painted.

The Corrosion Committee of the British Iron and Steel Research Association[3] investigated the effect of the nature of the basis steel on the performance of protective paints. The paints used were red lead and red oxide paints in a linseed oil medium. The corrosion resistance of the basis metals ranged from that of materials that probably performed like the open hearth iron in the present investigation to something a little better than the copper steel in these tests. The most marked effects were observed in the most corrosive industrial atmosphere where the life to failure of the four-coat paint system on the most corrosion resistant of the steels was about twice that on the

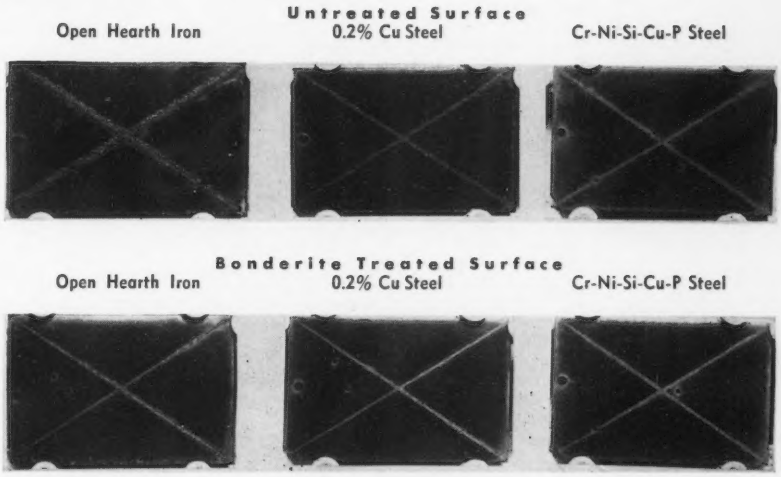


Figure 1—Effect of surface treatment on painted steels exposed two months in atmosphere 80 feet from ocean at Kure Beach, N. C.

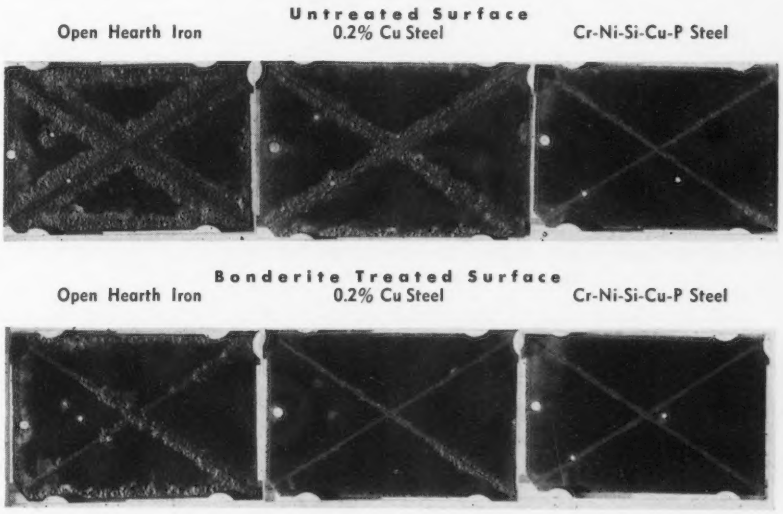


Figure 2—Effect of surface treatment on painted steels exposed eight months in atmosphere 80 feet from ocean at Kure Beach, N. C.

## Abstract

The investigation provides at least a partial answer to the question as to whether improved atmospheric corrosion resistance of alloy steels is advantageous when they are painted. Steels showed a 20:1 difference in corrosion loss between an exceptionally low copper content open hearth iron and typical low alloy high strength steel. A common automobile paint system was used—a pigmented baking alkyd primer with pigmented baking urea modified, alkyd top coats, with and without zinc phosphate (Bonderite) pretreatment. Test panels were exposed 80 and 800 feet from the ocean at Kure Beach, N. C., in an industrial atmosphere at Bayonne, N. J. and in a rural atmosphere at Morenci, Mich. Principal findings were: 1. Low alloy steel performed best; copper steel next. Low copper content open hearth iron worst painted or bare. 2. Zinc phosphate pretreatment improved performance of all painted steels, the advantage increasing with severity of the atmosphere and vulnerability of steels. 3. Best performance was that of low alloy high strength steel, zinc phosphate pretreated. 4. A few weeks' exposure 80 feet from ocean led to same conclusions as exposure for much longer periods elsewhere. 5. Marine atmosphere 800 feet from ocean was less damaging to bare, but more damaging to painted steel than Bayonne industrial atmosphere.

* A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 10-14, 1953.

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**JAMES A. BOYLAN—Presently in charge of the Technical Service Section of the Technical Division of The Parker Rust Proof Company, Detroit. He started work for the Parker Company in 1929 in the testing laboratory and has spent most of his time since in the field of corrosion testing and surface treatment.**

least corrosion resistant iron. In less corrosive atmospheres, differences among the steels tested were not appreciable.

Previously Hudson[4] had concluded: "If maintenance (of paint coatings) can only be infrequent or will be incomplete—it will be advisable to use a low alloy steel or wrought iron with increased resistance to rusting. This will certainly be the case where it is desired to reduce maintenance costs to a minimum by increasing the permissible interval between repaintings to the utmost practicable limit, or where local damage to the paint is liable to occur in service."

In addition to the principal purpose of the present tests, the program provided information on such points as: the effects of composition on the corrosion of the bare steels, the value of a zinc phosphate pretreatment, effects of scribe marks and differences in the corrosivity of marine, industrial and rural atmospheres with respect to both bare and coated specimens.

**TABLE I—Compositions of Steels**

| Material | COMPOSITION—PERCENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | C | Mn | P | S | Si | Cu | Ni | Cr |
| Open Hearth Iron | .016 | .016 | .005 | .029 | .002 | .014 | .05 | .... |
| 0.2 percent Cu Low Alloy | .046 | .40 | .007 | .019 | .005 | .21 | .... | .07 |
| Cr-Ni-Si-Cu-P Steel | .08 | .30 | .09 | .020 | .65 | .41 | .48 | .85 |

**TABLE II**

**Average Weights and Thicknesses of Paint Films on Test Panels Exposed 80 Feet from Ocean at Kure Beach, North Carolina**

| | Open Hearth Iron | | Copper Steel | | Alloy Steel | |
|---|---|---|---|---|---|---|
| | Wt., Grams | Thickness Mils | Wt., Grams | Thickness Mils | Wt., Grams | Thickness Mils |
| Continuous Coating Over Bare Steel | 3.41 | 1.8 | 3.49 | 2.0 | 3.39 | 2.0 |
| Scribed Coating Over Bare Steel | 3.51 | 1.7 | 3.61 | 2.0 | 3.59 | 2.2 |
| Continuous Coating Over Zinc Phosphate Treated Steel | 4.11 | 2.2 | 4.25 | 2.3 | 4.12 | 2.7 |
| Scribed Coating Over Zinc Phosphate Treated Steel | 3.60 | 2.0 | 3.93 | 2.2 | 3.58 | 2.3 |
| Prime Coat Only | 1.29 | 1.0 | 1.54 | 1.2 | 1.31 | 1.1 |
| Prime Coat Over Zinc Phosphate Treated Steel | 1.14 | 1.0 | 1.24 | 1.1 | 1.11 | 1.2 |

## Nature of Coatings:

Specimens measuring 4 x 6 inches were exposed in the following conditions:

A. Bare
B. Coated with a continuous black automobile finish applied over bare untreated steel.
C. Same as B except scribed through to bare metal.
D. Coated with a continuous black automobile finish applied over zinc phosphate (Bonderite*) treated steel.
E. Same as D except scribed through to bare metal.
F. Coated with a continuous primer applied over bare untreated steel.
G. Same as F except applied over zinc phosphate (Bonderite) treated steel.

The automobile body finish was described as:

1st coat: A highly pigmented sanding baking primer surfacer based on an alkyd vehicle.

2nd coat: A low pigmented baking urea modified alkyd.

3rd & 4th coats: A black pigmented urea modified alkyd baking enamel.

## Test Procedure

Six kinds of steel were tested:

1. An exceptionally low copper content (0.014 percent Cu) open hearth iron known, because of its deficiency in copper, to be highly vulnerable to atmospheric corrosion.
2. A representative copper bearing steel (0.2 percent Cu).
3. A commercial low alloy high strength steel of the nickel copper type.
4. A commercial low alloy high strength steel of the chromium, nickel, silicon, copper, phosphorus type.
5. An experimental steel which contained a total of about 0.5 percent nickel plus copper.
6. A steel supposed to be representative of standard automobile body stock, but which upon subsequent analysis was found to carry an unusually high content of residual copper (0.20 percent) as compared to a normal residual copper content of 0.08 percent. (Samples of steel from corroded automobiles have frequently shown copper contents under 0.05 percent.)

Comparison of the results on steels 1, 2 and 4 will suffice to disclose the principal results of these tests and illustrate the nature and magnitude of the effects observed. The compositions of these steels are given in Table I.

The paint films on the specimens were all weighed and measured. The average weights and thicknesses of the films on the panels exposed 80 feet from the ocean at Kure Beach are shown in Table II.

* Registered trademark, Parker Rust Proof Company.

The purpose of the scribe marks was to permit observations of the extent to which film breakdown and corrosion would creep from a uniform edge.

The complete coating systems described were applied to both surfaces and the edges of the specimens. The specimens which carried the prime coats only were included because this coating without the top coats is what is used on the undersides of automobile bodies.

**TABLE IIIa**

**Effect of Composition of Steel on Corrosion Under Paint Films 80 Feet from Ocean at Kure Beach, North Carolina, for 365 Days**

| Condition of Exposure | CORROSION RATES | | | | | |
|---|---|---|---|---|---|---|
| | Open Hearth Iron | | 0.2% Cu Steel | | Cr-Ni-Si-Cu Steel | |
| | mdd* | ipy** | mdd | ipy | mdd | ipy |
| Bare | 212 | 0.039 | 28 | 0.005 | 13 | 0.002 |
| Continuous Finish Over Bare Steel | 55 | 0.010 | 5 | 0.0009 | 1 | 0.0002 |
| Scribed Finish Over Bare Steel | 97 | 0.018 | 15 | 0.003 | 1 | 0.0002 |
| Continuous Finish Over Phosphate Treated Steel | 26 | 0.005 | 2 | 0.0004 | 0.3 | <0.0001 |
| Scribed Finish Over Phosphate Treated Steel | 40 | 0.007 | 3 | 0.0006 | 0.3 | <0.0001 |
| Primer Only Over Bare Steel | 210 | 0.039 | 19 | 0.003 | 7 | 0.001 |
| Primer Only Over Phosphate Treated Steel | 133 | 0.024 | 13 | 0.002 | 6 | 0.001 |

* Mg. per sq. dm. per day.
** Inches penetration per year.

**TABLE IIIb**

**Effect of Composition of Steel on Corrosion Under Paint Films 800 Feet from Ocean at Kure Beach, North Carolina, for 548 Days**

| Condition of Exposure | CORROSION RATES | | | | | |
|---|---|---|---|---|---|---|
| | Open Hearth Iron | | 0.2% Cu Steel | | Cr-Ni-Si-Cu Steel | |
| | mdd | ipy | mdd | ipy | mdd | ipy |
| Bare | 78 | 0.014 | 8 | 0.001 | 4 | 0.0007 |
| Continuous Finish Over Bare Steel | 14 | 0.003 | 1 | 0.0002 | 0.2 | <0.0001 |
| Scribed Finish Over Bare Steel | 20 | 0.004 | 0.7 | 0.0001 | 0.3 | <0.0001 |
| Continuous Finish Over Phosphate Treated Steel | 8 | 0.001 | 0.3 | <0.0001 | 0.2 | <0.0001 |
| Scribed Finish Over Phosphate Treated Steel | 6 | 0.001 | 0.3 | <0.0001 | .. | ..... |
| Primer Only Over Bare Steel | 70 | 0.013 | 5 | 0.0009 | 2 | 0.0004 |
| Primer Only Over Phosphate Treated Steel | 45 | 0.008 | 4 | 0.0007 | 2 | 0.0004 |

**TABLE IIIc**

**Effect of Composition of Steel on Corrosion Under Paint Films at Bayonne, New Jersey, for 564 Days**

| Condition of Exposure | CORROSION RATES | | | | | |
|---|---|---|---|---|---|---|
| | Open Hearth Iron | | 0.2% Cu Steel | | Cr-Ni-Si-Cu Steel | |
| | mdd | ipy | mdd | ipy | mdd | ipy |
| Bare | 69 | 0.013 | 10 | 0.002 | 5 | 0.0009 |
| Continuous Finish Over Bare Steel | 5 | 0.0009 | 0.2 | <0.0001 | 0.3 | <0.0001 |
| Scribed Finish Over Bare Steel | 7 | 0.001 | 0.3 | <0.0001 | 0.3 | <0.0001 |
| Continuous Finish Over Phosphate Treated Steel | 2 | 0.0004 | 0.05 | <0.0001 | 0.09 | <0.0001 |
| Scribed Finish Over Phosphate Treated Steel | 3 | 0.0005 | 0.09 | <0.0001 | 0.2 | <0.0001 |
| Primer Only Over Bare Steel | 33 | 0.006 | 6 | 0.001 | 3 | 0.0005 |
| Primer Only Over Phosphate Treated Steel | 33 | 0.006 | 7 | 0.001 | 2 | 0.0004 |

**TABLE IIId**

**Effect of Composition of Steel on Corrosion Under Paint Films at Morenci, Michigan, for 555 Days**

| Condition of Exposure | CORROSION RATES | | | | | |
|---|---|---|---|---|---|---|
| | Open Hearth Iron | | 0.2% Cu Steel | | Cr-Ni-Si-Cu-P Steel | |
| | mdd | ipy | mdd | ipy | mdd | ipy |
| Bare | 10 | 0.002 | 5 | 0.0009 | 3 | 0.0006 |
| Continuous Finish Over Bare Steel | 2 | 0.0004 | 0.03 | <0.0001 | 0.06 | <0.0001 |
| Scribed Finish Over Bare Steel | 3 | 0.0006 | 0.08 | <0.0001 | 0.08 | <0.0001 |
| Continuous Finish Over Phosphate Treated Steel | 0.5 | <0.0001 | .. | ..... | 0.04 | <0.0001 |
| Scribed Finish Over Phosphate Treated Steel | 2 | 0.0004 | 0.05 | <0.0001 | 0.02 | <0.0001 |
| Primer Only Over Bare Steel | 6 | 0.001 | 3 | 0.0006 | 2 | 0.0004 |
| Primer Only Over Phosphate Treated Steel | 5 | 0.0009 | 3 | 0.0006 | 2 | 0.0004 |

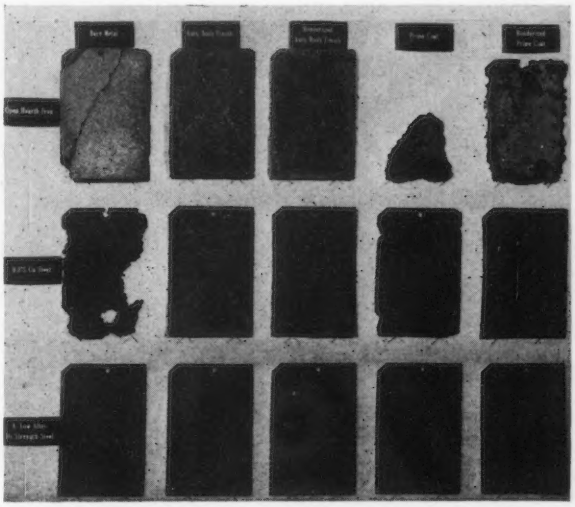

Figure 3—Appearance of specimens after expousre for 16 months in the atmosphere 80 feet from the ocean, Kure Beach, N. C.

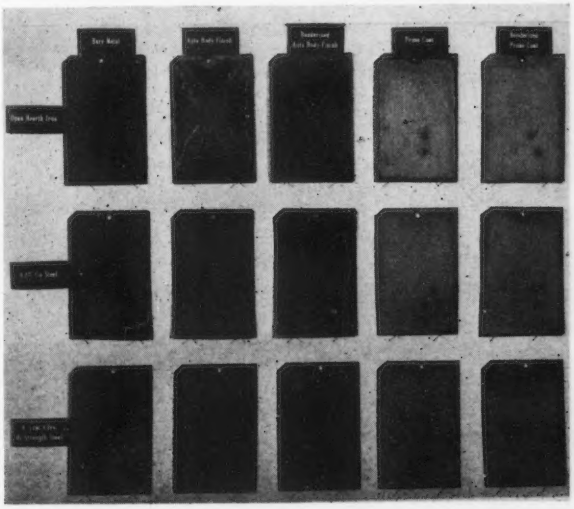

Figure 4—Appearance of specimens exposed for two years in the atmosphere at Morenci, Mich.

**TABLE IV**

**Advantages of Alloy Steel Over Open Hearth Iron and Copper Steel**

**Exposed in Different Conditions 80 Feet From the Ocean at Kure Beach, North Carolina, for One Year**

| Condition | Advantage of Alloy Steel Based on Weight Loss Ratio* | |
|---|---|---|
| | Over Open Hearth Iron | Over Copper Steel |
| Bare | 16 | 2 |
| Prime Coating Over Zinc Phosphate Treated Steel | 24 | 2 |
| Prime Coating Over Bare Steel | 28 | 3 |
| Continuous Coating Over Bare Steel | 37 | 3 |
| Continuous Coating Over Zinc Phosphate Treated Steel | 65 | 4 |
| Scribed Coating Over Bare Steel | 68 | 10 |
| Scribed Coating Over Zinc Phosphate Treated Steel | 94 | 6 |

* Determined by dividing weight losses of alloy steel specimens into weight osses of other specimens.

**TABLE V**

**Advantages of Zinc Phosphate Treatment on Steels**

**Exposed in Different Conditions 80 Feet From the Ocean at Kure Beach, North Carolina, for One Year**

| Condition | Advantage of Treatment Based on Weight Loss Ratio* | | |
|---|---|---|---|
| | Alloy Steel | Open Hearth Iron | Copper Steel |
| Continuous Complete Coating | 3.8 | 2.1 | 2.9 |
| Scribed Complete Coating | 3.4 | 2.5 | 6.1 |
| Continuous Primer Only | 1.3 | 1.6 | 1.4 |

* Determined by dividing weight losses of treated specimens into weight losses of untreated specimens.

### Test Locations:

Specimens representing each steel and coating condition were exposed in September 1948 in duplicate at four locations:

1. In the marine (sea spray) atmosphere 80 feet from the ocean and facing it (east) at Kure Beach, N. C.
2. In the marine atmosphere 800 feet from the ocean at Kure Beach, N. C. facing south.
3. In the industrial atmosphere at Bayonne, N. J. facing south.
4. In the rural atmosphere at Morenci, Michigan facing south.

The specimens at Morenci, Michigan, were placed at an angle of 45 degrees from the horizontal; those at the other test locations were at 30 degrees from the horizontal.

### Treatment of Specimens After Exposure:

Specimens removed from test were treated for further examination as follows:

A. Loose dust and rust were removed by brushing with a paint brush.

B. The panels were rinsed in clean water and force dried at 200 degrees F.

C. The panels were weighed.

D. Panels were treated with a hot stripping solution to remove organic finishes, rinsed in water and then degreased in trichlorethylene vapor.

E. Corrosion products were removed by immersion in a solution made up to contain:

One hundred parts by weight of hydrochloric acid
Two parts by weight of antimony trioxide
Five parts by weight of stannous chloride

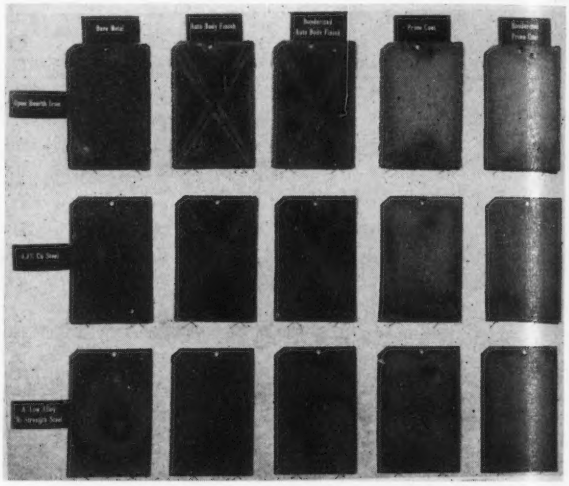

Figure 5—Appearance of the specimens exposed for two years in the atmosphere at Bayonne, N. J.

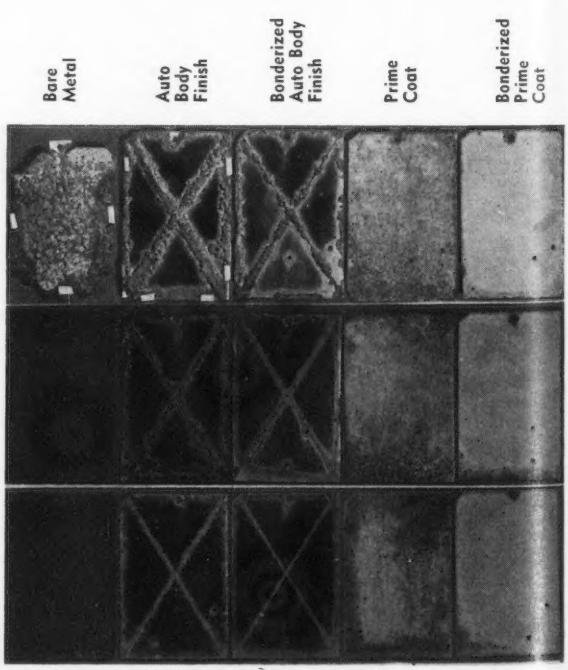


Figure 6—Appearance of specimens after exposure for two years in the atmosphere 800 feet from the ocean at Kure Beach, N. C.

F. The panels were dried and weighed.

In the case of the most severely corroded specimens of open hearth iron the rust was so loose that it was possible to remove all of it mechanically.

**Records of Performance:**

The exposure conditions 80 feet from the ocean at Kure Beach were exceptionally severe so that it was possible to observe marked differences in performance quite early in the test. Inspections were made after 23 days and again after 56 days at which time the specimens were photographed as shown in Figure 1. These early inspections showed that the extent of corrosion and paint failure along the scribe marks was being influenced by the composition of the steel and that the zinc phosphate treatment was effective in restraining paint failure.

A similar inspection of these specimens was made after they had been exposed 8 months, by which time corrosion had proceeded to the extent shown by Figure 2. By this time, the differences exhibited after 56 days had become much more pronounced and the advantages of the alloy content and the zinc phosphate pretreatment were clearly evident.

After exposure for another four months (one year total) one set was removed for weight loss determinations. Results are shown in Table IIIa. These data are broken down further in Tables IV and V to facilitate observations of some effects of steel composition and of the zinc phosphate treatment.

The balance of the specimens were continued in test 80 feet from the ocean at Kure Beach for a total of 16 months, at which time they were photographed as shown by Figure 3.

Of the specimens exposed at the other test locations, one set was removed after exposure for 18 months and the balance after 24 months. The 18-month specimens were cleaned and weighed with the results shown in Tables IIIb, IIIc, and IIId. The 24-month specimens were photographed as shown in Figures 4, 5 and 6. These specimens, along with the 16-month specimens from the site 80 feet from the ocean at Kure Beach have been preserved as they were for permanent record.

The performance of the specimens at these other test sites was in line with their behavior 80 feet from the ocean at Kure Beach even though the extent of deterioration was much less—especially in the rural atmosphere at Morenci, Michigan.

Comparing the industrial atmosphere at Bayonne with the marine atmosphere at Kure Beach, it will be observed that the marine atmosphere was more damaging to the coated specimens, while the industrial atmosphere was slightly more corrosive to the bare steels.

The numerical data and the appearance of the specimens were in harmony and established:

A. The advantage of the low alloy high strength steel over the copper steel and the open hearth iron in resisting atmospheric corrosion.
B. The advantage of the copper steel over the open hearth iron in resisting atmospheric corrosion.
C. The advantage of the more corrosion resistant steels whether bare or painted—the extent of this being even greater with the painted specimens than with the bare ones and being most valuable in the most corrosive atmosphere.
D. The protective value of the organic coatings, which was enhanced by providing a more corrosion resistant base.
E. The advantage of the zinc phosphate treatment under the primer alone, as well as under the complete paint system. The effect was greatest with the most corrosion resistant steel, but was most needed with the most vulnerable material and most important in the most corrosive atmosphere.
F. The effect of scribing in aggravating paint failure and corrosion—especially on the more vulnerable steels and when there was no treatment with zinc phosphate.
G. The advantage of combining the most corrosion resistant steel with the zinc phosphate treatment under the complete paint system—especially in the most corrosive atmosphere.
H. The greater and faster deterioration 80 feet from the ocean at Kure Beach than at the other test sites. This permitted the principal conclusions to be reached in the shortest time, e.g. after exposure for only 56 days.

## Acknowledgments

The authors acknowledge the help of their associates in preparing and exposing the test panels, especially R. B. Teel, assistant manager of the Inco Harbor Island Test Station, K. Henderson of the Inco staff in New York who photographed most of the specimens, Marguerite Bebbington of the Inco staff in New York who kept track of the tests and tabulated the data, H. E. Dean and W. M. Sennett of the Technical Division of the Parker Rust Proof Company, who obtained the corrosion data and made some of the photographs.

## References

1. H. A. Nelson. The Effect of Adding Zinc Oxide to Iron Oxide Paints. Research Bulletin, New Jersey Zinc Company, 1929.
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3. First, Second, Third, Fourth and Fifth Reports of the Corrosion Committee, Iron & Steel Institute; Special Reports No. 1 (1931), 5 (1934), 8 (1935), 13 (1936) and 21 (1938) summarized by F. Fancutt and J. C. Hudson. The Work of the Protective Coatings (Corrosion) Sub-Committee. *Corrosion*, **8**, No. 11, 366 (1952) Nov.
4. J. C. Hudson. The Corrosion of Iron and Steel. Chapman and Hall, Ltd., London, 1940, p. 105.

# Discussions

## Statistics—A Useful Tool for the Examination of Corrosion Data by Charles F. Lewis. CORROSION, Vol. 9, No. 1, 38-43 (1953) Jan.

**Discussion by A. H. DuRose, Harshaw Chemical Comany, Cleveland, O.:**

Mr. Lewis is to be complimented on a clear presentation of a subject which is usually difficult for a novice like myself to grasp. However for the specific data dealt with it seems that a few refinements would allow for better interpretation of the data and still maintain the clarity of presentation.

First, examination of corrosion data will usually show that the greater the degree of corrosion the more erratic it will become; in other words, a log-normal distribution. By plotting the unlogged data on probability paper it appeared that the high value 29 (in the iron-containing data) was a maverick and it was rejected. However by plotting the data on logarithmic probability paper a fairly straight line is obtained indicating that this datum follows the usual pattern of corrosion data. Note that the range for the iron-free data is greater than that of the iron-containing data even when the value 29 is considered. The iron-containing data when plotted on logarithmic probability paper gives a line with a slight curve indicating that it would not make much difference in results whether the distribution was considered normal or lognormal. Actually not much difference in results is obtained even if the skewed distribution of the iron-containing data is considered to be normal. (See below.) The rejection of the value 29 however, is highly questionable.

Another question is why the t value 1.645 was used on data containing 4 or 5 values. It would be just as clear if the correct t value of 2.132 were used. The former would be used where n was large but not where n equals 5.

With the value 29 rejected the standard deviation given in the paper for the iron-containing series is 4.02. Calculation (both direct and from the slope) shows it to be closer to 3.3-3.7.

By not rejecting the value 29 and by using a t of 2.132 the following confidence limits for the average were obtained:

| | Iron-Free | Iron-Containing |
|---|---|---|
| Normal distribution assumed | 14.8-55.2 | 2 -21 |
| Lognormal distribution assumed | 14.0-59.6 | 4.25-18.9 |
| Arithmetic mean | 35 | 11.6 |
| Geometric mean | 28.9 | 8.95 |

The iron-free data appeared to follow a normal distribution slightly better than a lognormal distribution which accounts for the narrower confidence limits when calculated on a "normal" basis. The reverse is true for the iron-containing data.

In case I have made any arithmetical errors, the following detail is given:

| | Iron-Free | Iron-Containing |
|---|---|---|
| Arithmetic mean | 35 | 11.6 |
| Mean of logs | 1.46 | 0.952 |
| Standard deviation (unlogged) | 21.2 | 10.57 |
| Standard deviation of logs | 0.33 | 0.34 |
| Standard error (unlogged) | 9.5 | 4.53 |
| Standard error of logs | 0.147 | 0.152 |
| L (unlogged) | 20.2 | 9.65 |
| L of logs | 0.315 | 0.324 |

**Reply by Charles F. Lewis:**

Thank you indeed for your discussion of my little article on statistics which appeared recently in Corrosion magazine. I was amused to note that you call yourself a novice in one paragraph and then talk about log-normal distributions in the next. I'm afraid you are entirely too modest in classifying yourself as a novice. Be that as it may, you have raised a couple of excellent points, and I appreciate your remarks a lot.

Of course, it is always dangerous to make predictions from a given set of data unless one is thoroughly grounded in the technology of the subject to which the data pertain, I have not done too much on quantitative corrosion testing and so did not know that a log-normal plot is usually to be expected. However, I did plot both sets of data on log-normal paper and I could not see where it was much, if any, better fit than when plotted on straight normal. One must always be cautious in rejecting suspected mavericks, but in this case it seemed justified, hence the discussion was pointed in that direction. In any event the purpose of the paper was more to demonstrate the graphical technique involved rather than a critical interpretation of the data itself.

Students "t" was not used in this case because, as I understand it, his values are to be used when the variance is computed from the data. In this case the deviation moments will be about the sample mean rather than about the population mean. By using the graphical solution we obtain estimates of the population parameters from the fitted distribution function rather than from the data alone. Thus we have an independent estimate of the population values. Also, we have definite evidence of normality—or lack of it. Also, when the parent distribution of individuals is normal, the means of samples drawn from the distribution will also be normally distributed so why not use normal law for prediction? In other words, here we have certain information which Student assumes is not available and for lack of which he compensates by increasing his bracket. I may be entirely wrong, but that is the reasoning I used.

As a matter of comparison, below are the num-

ber of standard error units to contain 90 percent of the population as given by the several systems:

| | |
|---|---|
| Normal law | 1.645 |
| Student | 2.132 (for 4 Degrees of freedom) |
| Camp Meidell | 2.108 |
| Tchebycheff | 3.162 |

One may be certain that 90 percent or more will lie within the values set by the Tchebycheff inequality.

Which of these to use depends upon the amount of additional information as to the form of the parent distribution that one may have as a basis for forming a conclusion. Actually many people round the figure off at 2 even and then state the probability as being "of the order of 90 percent."

As to the numerical value of sigma prime estimated for the iron-containing data I stand corrected. In going over my notes, I see that I had plotted the first point at 17.5 percent instead of 12.5 percent where it should have been. The parameter taken from the least squares fit of a normal distribution to the four points are:

| | |
|---|---|
| Population average | 7.5 mils |
| Standard deviation | 3.27 mils |

I had missed this completely and I am glad you found it.

**Remarks by T. E. Wright, Aluminum Laboratories, Ltd.:**

We have found the article very interesting and have used Mr. Lewis' methods in connection with data obtained on the pitting rate of aluminum in Kingston, Ontario tapwater. When perforations occur in aluminum sheet being tested in the water there has often been some question as to whether two pits met or whether the perforation was caused by a pit corroding from one side. As multiple coupons are used for each test we were able to apply his methods to show where perforation was obviously due to two pits. While we could have applied existing techniques to show the same thing it was not until reading Mr. Lewis' article that we were aware of the simple manner in which our problem could be solved.

## The Present Status of Bacterial Corrosion Investigations in the United States. By Carl G. Deuber. CORROSION, Vol. 9, No. 2, 95-99 (1953) Mar.

**Discussion by W. F. Higgins, Magnesium Elektron, Ltd., Manchester, England:**

I have read with more than usual interest your contributor's assessment of the situation regarding bacterial corrosion in the U.S.A. (Carl G. Deuber—"Present Status of Bacterial Corrosion in the U.S.A.," Corrosion, No. 3, Vol. 9, March, 1953). If I may be allowed to venture a criticism of such an excellent review, I would suggest that Mr. Deuber gives too prominent a place to the effect of anaerobic bacteria in the process of corrosion. I believe that bacteria play a secondary role in the phenomenon rather than that they are the initiators of the process. It is true that in his final conclusions Mr. Deuber by implication admits soil conditions in general rather than bacteria in particular to be the governing factor, but the tenor of his article ascribes the observed effects primarily to the latter. The important point would seem to be that in anaerobic conditions, whether bacteria are present or not, the essential feature is the absence of protective film formation by oxygen on which the corrosion resistance of iron so greatly depends. Inequalities of stability of the metal surface from any cause lead, in the presence of even the weakest electrolytes, to breakdown of this film, and so to the formation of anodic areas and, of course, of equivalent cathodic areas.

Healing of these points of breakdown may be expected in the presence of an adequate supply of oxygen, or at least stifling of the reaction by the formation of suitably constituted corrosion products, but in the absence of oxygen the only limitation of the corrosion process must be by cathodic control, that is by polarization of the cathodes. This indeed might occur, to a degree which would be dependent largely on the rate of diffusion of the hydrogen; not sufficiently perhaps to prevent corrosion entirely, but greatly to limit it.

In the presence of *spirovibrio desulfuricans* however, even this protection is denied to the metal; depolarization is rapid and anodic dissolution proceeds unchecked. My point is that spirovibrio desulfuricans acts as many of its brethren do in other spheres; powerless to attack a healthy individual, it is avid to take advantage of adverse conditions which, in this case, are the transfer of electrons from the metal, brought about by the proximity of anions of electrochemical processes, and the consequent creation of anodic areas.

I have not referred to long line currents and the effect of differential aeration or of concentration cells, but all these and others must obviously play a part and in each and every case *spirovibrio desulfuricans* profits by the results: The bacteria aggravate the corrosive conditions but they do not produce them. They are the camp followers, not the van-guard. Worse still, long line currents especially may lead to the concentration of anions-sulfates, for example, at the anodic regions of a pipe wall. Surely it is not unreasonable to suppose that the mere concentration of sulfate at the pipe wall by electro-chemical processes encourages the development and multiplication of sulfate reducing bacteria in just those places—as is indeed found to be the case? Consider, Sir, that all the conditions usually ascribed to the depredations of *spirovibrio desulfuricans* can also be found in their absence in anaerobic conditions when cathodic protection has been applied to buried steel on which, to some degree, corrosion has already taken place. Black reduced oxides are produced with

clean bright metal below, brought about obviously by the reducing conditions, but not necessarily associated with corrosion—rather the reverse. Even the production of hydrogen sulfide by this means is probably not impossible if sulfate ions are initially present.

Now the point of practical importance is this: In considering the economics of prevention of corrosion in such circumstances by cathodic protection, it should not be lost sight of that, though relatively large currents may be required in the initial stages, firstly to offset the depredations of the bacteria in their consumption of cathodic hydrogen and secondly to maintain the pipe in a polarized, and therefore protected condition, this requirement will be rapidly reduced as alkaline conditions are established on the pipe. As Mr. Deuber rightly points out, the bacteria become quiescent above a pH of 9 to 9.5. Since in anaerobic conditions oxygen deplorization is not present and the bacteria at this pH are rendered impotent, cathodic protection should be very economical.

To sum up, Sir, I suggest that anaerobic bacteria of the type described must be regarded as merely secondary factors (though obviously of considerable importance unles controlled). Their true function is that of cathodic repolarizer and their suppression is a matter of rendering the conditions adjacent to the pipe line or other structure untenable by 1) making the pipe truly cathodic, 2) making the ground in immediate contact with it sufficiently alkaline and 3) promoting the migration of $SO_4$ ion from the pipe wall—all of which can be conveniently and simultaneously achieved by utilizing the principles of cathodic protection.

One other point: Mr. Deuber enumerates the use of insulating joints as one of the major corrective measures to reduce corrosion by bacterial influences. Though it is clear that such insulating joints will prevent or reduce the development of long line currents, I fail completely to grasp how they can directly reduce purely bacterial corrosion, which is a local phenomenon.

The only way in which insulating joints might influence anaerobic corrosion would seem to be by suppressing long line currents which in turn would reduce the tendency for sulfate to be concentrated at the anodes. This I believe is what happens and it confirms my view that the bacteria take advantage of an existing situation rather than that they produce it.

**Reply by Carl G. Deuber:**

The views of Mr. W. F. Higgins are sincerely appreciated. They clearly indicate the requirement for additional research on the fundamental aspects of bacterial corrosion.

From a corrosion engineering standpoint the outstanding American contribution appears to be the emphasis upon the ecological factor of poor soil aeration with methods for measuring this in terms of soil redox data.

# Topic of the Month

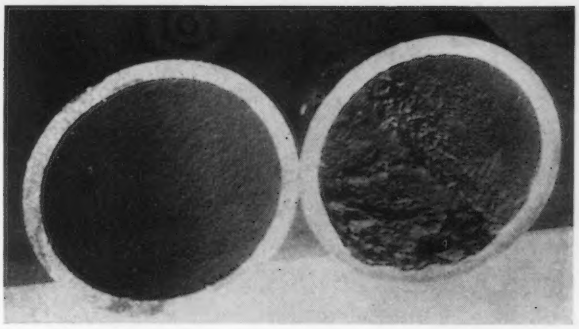

Figure 1—Difference in effect of treated and untreated condensate.

## Amines for Corrosion Prevention in Steam Condensate Systems

By C. JACKLIN*

CORROSION in the steam-condensate system of power generating utilities, process industries and steam heating plants has long challenged the chemist and engineer. Prevention has been attempted by various chemical means. In turbines, heaters and lines, particularly in large extensive systems, corrosion damages equipment and the corrosion products often are carried to the boiler to deposit and cause additional problems.

In order to provide continuous and complete protection against corrosion of all parts of a steam-condensate system, a treatment must possess certain definite characteristics which will enable it to remain uniformly distributed in the system. It must also be chemically stable at all temperatures existing in the system.

Amine-type chemicals have been used to control corrosion in steam condensate systems for several years but only recently has their use been extended to the successful and economical protection of high pressure, low make-up systems. Laboratory and field studies of numerous materials have revealed only a few amines that display the required properties. Of the amines in this group, morpholine is outstanding because of its stability at high temperatures, and its ability to condense with the initial condensate.

The vapor pressure of morpholine is such that even at low concentrations in the boiler water it will vaporize and the proper proportion will condense with the first droplets of condensate which form in the system. This assures protection to a critically important part of the cycle. Most other presently known amines have vapor pressures which are too low or too high and consequently either remain in the boiler water or fail to condense in the first formed droplets. In either case, an important portion of the system may be left unprotected.

Low pressure systems usually contain considerable amounts of carbon dioxide as a result of decomposition of bicarbonates and carbonates in the feedwater or evaporator system. This carbon dioxide, when dissolved in the condensate, reduces the pH value of the condensate and makes it acid enough to be highly corrosive to steel. In modern high pressure systems, the amount of carbon dioxide in the system is usually kept at a very low value by careful pre-conditioning of either feedwater or evaporated make-up.

However, even this very pure, nearly neutral condensate, essentially free of acidic anions, has a sufficiently low pH value to dissolve measurable quantities of iron. When large volumes of condensate are circulated, quantities of iron removed from the exposed surfaces by this reaction alone, often present a serious problem. It is, therefore, necessary to provide control of the pH in addition to the proper neutralization of carbon dioxide and other acidic components.

Morpholine has the following important advantages as a treatment for prevention of corrosion in steam condensate systems:

1. It neutralizes carbon dioxide and other acidic components in the steam and condensate.
2. It maintains proper pH in all parts of the system, particularly in areas of initial condensation.
3. It is stable at all temperatures found in modern steam generating systems and boiler water conditions usually associated with them.
4. It is readily available in safe, convenient, solution form.

The figure vividly illustrates the result of morpholine treatment. The right hand pipe is representative of conditions found in a typical condensate system after four years with no treatment. The left hand pipe was removed from the same system after treatment with morpholine for four years.

* Director, Engineering Research, National Aluminate Corp., Chicago.

# NACE News

## Northeast-Buffalo Meeting Features Three Papers, Movie

Registrants at the May 19 joint meeting held in Buffalo, N. Y. by the Northeast Regional Division and the Western New York section heard papers presented by Dr. Mars G. Fontana, Ohio State University, Dr. A. L. Alexander, Naval Research Laboratories, and Harold Rosenbloom, Thompson and Company. An informative sound and color film presented by Howard Vanderpool, Metallizing Engineering Co. completed the technical program. Dr. Fontana spoke on "Corrosion in the Chemical Industry," Dr. Alexander on "Role of Inhibited Pigments in Metal Protection," and Mr. Rosenbloom on "The Chemistry of Surface Conversion Coatings." The film presented by Mr. Vanderpool was "Application of Metallizing."

The meeting was closed with an announcement of the results of the election for officers of the Western New York section. Elected were: James E. Shields, Consulting Engineer, Niagara Falls, chairman; Joseph E. Thornberg, Hooker Electrochemical Co., Niagara Falls, vice-chairman; William R. Wardrop, Metal-Cladding, Inc., Buffalo, secretary-treasurer.

## Radiant Heating Systems Discussed at Meeting Of Pittsburgh Section

New officers for the Pittsburgh Section were elected at the May meeting of the Section. Members heard a paper, "Corrosion of Radiant Heating Systems" and following the business meeting gave their attention to a buffet lunch.

New officers elected are Frank E. Costanzo, The Manufacturers' Light and Heat Co., Pittsburgh, Pa., chairman; Wayne W. Binger, Aluminum Company of America, New Kensington, Pa., vice-chairman; Thomas T. Royston, Royston Laboratories, Inc., Blawnox, Pa., secretary; and William G. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa., treasurer.

Because of illness, R. H. Peifer, author of "Corrosion of Radiant Heating Systems," was unable to appear. His paper was read by N. P. Peifer.

## Boston Section

At a recent meeting the Board of Governors of the Northeast Regional Division approved the Rules and Regulations submitted by the Greater Boston Section. Approval of the governing rules was the final organizational step in forming the section.

Boston Section has scheduled meetings as follows: 1953—October 14, December 2. 1954—February 3, May 5.

## Color Movie Shown On Pipeline Wrap to Baltimore Section

Baltimore Section members attending the April 21 meeting saw a color movie and heard J. B. Roadhouse of Owens-Corning Fiberglas Corp, who spoke on "The Use of Fiberglas in Wrapping Underground Pipelines."

Ernest Seay, Jr., Chesapeake and Potomac Telephone Company of Virginia, gave a brief description of the activities of the Tidewater Corrosion Engineering Committee which is attempting to mitigate electrolysis in the Tidewater area by resistance bonding and cathodic protection techniques. Mr. Seay is chairman of the committee.

Among the 20 members and six guests attending were: Murray H. Owen, manager of the Baltimore branch of Owens-Corning; George E. Best, chairman of the Northeast Region and George Tompkins of the Chesapeake and Potomac Telephone Co. of Virginia.

Risque L. Benedict, secretary-treasurer, reported that membership in the Baltimore Section had increased to 124.

Baltimore Section of NACE has scheduled meetings for the remainder of this year as follows: October 20 and December 1. These meeting dates were reported incorrectly as those of Boston Section in May Corrosion.

## Officers Are Installed By St. Louis Section

New officers of the Greater St. Louis Section were installed at the close of the May 11 meeting, according to William J. Ries, new vice-chairman. A fellowship hour preceded the banquet attended by 22 members and guests. The meeting was the last to be held until September when regular monthly meetings will be resumed.

"Organic Inhibitors in the Petroleum and Chemical Industries," was the technical paper. It was delivered by Vice-Chairman Ries who is associated with the Tretolite Co. in Webster Groves, Mo.

## Texas A & M Short Course To Be Given Sept. 22-25

A short course on corrosion will be given at Texas A & M College, College Station, Texas, September 22-25 inclusive. Registration will be limited and arrangements are being made for housing and feeding at the university.

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The cost of advertising in CORROSION per thousand readers has diminished each year since the magazine was founded.

## Papers on Plastics, Water Treatment Heard At Philadelphia Meet

Philadelphia Section members who attended the May 8 meeting heard two technical papers. Plastics as Materials of Construction was given by W. M. Bruner, Polychemicals Department, E. I. duPont de Nemours & Co., and Water Treatment for Corrosion Control in Air Conditioning Equipment, by Dr. Sidney Sussman, Water Service Laboratories, Inc.

Dr. Bruner said plastics are being used on an ever increasing scale and that evidence is mounting that they are more suitable than metals for some industrial jobs. He cited use of plastics in making pipe and automobile bodies as examples.

Nineteen types of plastics and elastomers were listed as commercially important for structural applications. Some properties of plastics discussed were: chemical and solvent resistance, maximum service temperature, creep or cold flow, flexural fatigue, impact strength, stiffness, tensile strength, elongation, specific gravity and water absorption. Dr. Bruner said adoption of standard codes along with increasing knowledge of fabrication and field assembly would boost use of plastics in the chemical, building, equipment and transportation industries.

In his talk on Water Treatment for Corrosion Control in Air Conditioning Equipment, Dr. Sussman emphasized that effective corrosion control in air conditioning equipment depends on proper attention to design, correct operation and maintenance and the correct and continuous application of treatment chemicals.

Air conditioning systems may include one or more of three types of water circuits: Once through. Open re-circulating. Closed re-circulating. Dr. Sussman showed sketches of typical air conditioning systems including the circuits and illustrating various types of evaporative cooling equipment.

Where once-through water is corrosive because of brackishness or high carbon dioxide content economically, it is better to choose corrosion-resistant materials of construction. In discussing open re-circulating systems he said that in areas having a low alkalinity water supply and heavy atmospheric contamination unusually severe corrosion problems are encountered in evaporative cooling equipment. He showed numerous examples of severe corrosion by circulating waters in which pH went as low as 2.8. Test coupon data were presented showing the extent of corrosion of mild steel in untreated, chromate treated and silicate-treated cooling towers and evaporative condensers in the New York and Philadelphia Metropolitan areas, Concerning closed re-circulating systems, Dr. Sussman said it is possible for corrosion to occur, but that water treatment is the principal answer.

## Middle East Corrosion Problems Discussed At Atlanta Meeting

Unusual corrosion problems of Arabia and the Middle East together with many interesting sidelights on the customs and characteristics of native and imported labor were related to members and guests attending the June meeting of the Atlanta Section. NACE member E. B. Ayers presented the talk which was illustrated by slides. Among the corrosion problems he discussed were wind erosion over pipe lines at camel crossings and salt water corrosion on docking facilities.

According to J. Flynn Johnston, chairman, the Atlanta Section "shows signs of healthy development." There were 30 members and guests at the meeting.

## Birmingham Selected For South East Fall Meeting November 12

The 1953 Fall Meeting of the Southeast Region will be held in Birmingham, Ala., November 12, 1953, it was decided at the Spring Meeting held at the Hotel Patten, Chattanooga, Tenn., May 7. Ed. Vines, Koppers Co., Inc., will serve as program-arrangements chairman.

Selection of Birmingham as the meeting place was in part due to a desire on the part of region members to lend support to Birmingham NACE members in their efforts to organize a local section.

Members attending the Spring Meeting heard five papers presented, went on a conducted tour through duPont's Chattanooga Nylon plant, attended a fellowship hour and banquet and sat in on a panel discussion of the papers presented in the morning session with the speakers as members of the panel and Dr. Ivy Parker as moderator.

Titles of the papers and the speakers who presented them were Positive Polarity Grounding of DC Supply Equipment in Mining Traction Systems, by S. A. Gibson, Tennessee Coal, Iron and Railroad Co., Division of United States Steel Corp.; Thirty Years Experience with Protective Coatings, R. L. Wray, Aluminum Company of America; Material Problems in Handling Commercial and/or Domestic Water Supplies, by Martin Flentje of American Waterworks Service, Inc.; Some Factors To Be Considered in the Application of Certain Austenitic Stainless Steels, by F. L. Whitney of Monsanto Chemical Co. and Engineering Materials in the Textile Industry by H. C. Moss of duPont.

Records show 42 members and 20 guests attended.

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Manuscripts of material on corrosion are accepted without invitation for review by NACE. Authors are advised to secure in advance of preparing their manuscripts a copy of the publication "Guide for the Preparation and Presentation of Papers," sent free.

**SEND IN NEWS**
**for August**
**CORROSION**
**Before July 10**

## *Paris Meeting Lists 3 Corrosion Papers*

Three papers of corrosion interest are included in the program of the European Conference on Chemical Engineering to be held in Paris in connection with the 26th International Congress of the Chemical Industry opening Monday, June 22. These papers are: Adsorption and Its Place in Chemical Engineering Research by A. Guyer, Zurich; Pollution of the Atmosphere by Chemical Plant by G. Bozza, Milan; Adsorption and Catalysts by A. Nasini, Turin.

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Canadian membership in NACE increased more than 100 percent during 1953.

## Cavanagh Elected N. Central Director

W. R. Cavanagh, Parker Rust Proofing Co., Detroit has been elected to a 3-year term as director of North Central Region, succeeding Frank L. Whitney, Jr.

Jack H. LoPrete, Spray Coat Engineers, Detroit, is region chairman.

A news story in the May issue of Corrosion incorrectly reported the election of Mr. Cavanagh as chairman. Apologies are offered to all persons mentioned.

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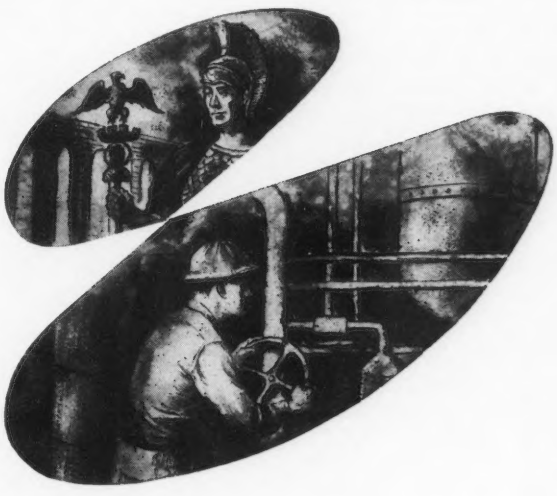
The cost of advertising in Corrosion per thousand readers has diminished each year since the magazine was founded.



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## Jacksonville Hears 3 Technical Papers At First Meeting

For its inaugural meeting, the newly organized Jacksonville, Florida, Section planned a dynamic, comprehensive program lasting more than half a day and featuring three technical papers, an address by NACE official, a fellowship hour and dinner at the Roosevelt Hotel.

The mailed announcement of the program urged members to attend and made a strong appeal to those whose work concerns corrosion to join the Jacksonville Section.

Papers and their authors were: "Cathodic Protection in Steam Power Plants," by Joseph B. Prime, corrosion engineer, Florida Power and Light Co., Miami, Fla.; "Underground Coatings," by Ernie Liggett, Johns-Manville Corp.; "Coatings Research and Coatings Application in Atomic Energy Installations," by Clyde Watson, Oak Ridge National Laboratory, Chemical Technology Div., Oak Ridge, Tenn.

Banquet speaker on the program was Dr. Ivy Parker, editor of CORROSION, who spoke on "Sources of Information on Corrosion." The program was scheduled to begin at 1:30 pm and end with dinner starting at 7 pm.

## *Beard Is Elected President of ASTM*

New officers for the American Society for Testing Materials for 1953-54 announced at the society's annual meeting in Atlantic City June 28-July 3 are as follows:

Leslie C. Beard, Jr., Assistant Director, Socony-Vacuum Laboratories, Socony-Vacuum Oil Co., New York City, president. Mr. Beard is author of many papers on petroleum technology and has been active for many years in ASTM's Committee D-2 on Petroleum Products and Lubricants among others.

Claire H. Fellows, Director of the Engineering Laboratory and Research Department of Detroit Edison Co., vice-president. He has been with Detroit Edison since 1919. A member of ASTM for many years, he has been a director for two terms and is active in the work of Committee D-9 on Electrical Insulating Materials; D-19 on Industrial Water; D-2 on Petroleum Products and Lubricants and Commitee A-5 on Corrosion of Iron and Steel. Mr. Fellows has served as section officer of Detroit's NACE's Detroit Section.

Named members of the board of directors were Neil A. Fowler, General Box Co., Des Plaines, Ill.; Richard T. Kropf, Belding Heminway Corticelli, New York City; Theodore E. Olt, Armco Steel Corp., Middletown, Ohio; John R. Townsend, Sandia Corp., Sandia Base, Albuquerque, N. M.; Kenneth B. Woods, Purdue University, Lafayette, Ind.

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In 1952, for every page of advertising published in CORROSION two pages of editorial matter were published.

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Of the editorial material published in CORROSION in 1952, 77 percent was of reference value.

## Teche Section Learns Of Brines, Corrosion Chemistry at Session

For the Teche Section's June meeting, the technical subject was "Chemical Study of Brines and Application of Chemistry to Corrosion," and the speaker was Maryann Duggan of the Magnolia Petroleum Co., research department, Dallas, Tex. The meeting, held at Toby's Oak Grove, Lafayette, La., was the last until the second Tuesday of September.

Miss Duggan explained that solution or pitting corrosion is seldom present where there is no water and that corrosion is basically an electrochemical process or transfer of electrons. In order for electrons to be transferred or ions to be lost from a piece of steel, water must act as the medium of transfer. Dissolved constituents in the water permit the corrosion rate to be fast or slow. She gave examples of corrosion associated with water in gas condensate wells, scrubber vessels and heat exchangers, products pipe lines and underground corrosion.

She described the dissolved constituents of water and showed samples illustrating the effect of exposures to these constituents. She concluded her illustrated talk by advising her listeners with corrosion problems to get a good analysis of the water and that a prime prerequisite for good analysis was a good sample.

Oil and Gas Production and Transmission Corrosion Problems, by M. J. Olive of Arkansas Natural Gas Corp., Shreveport, La., was the feature of the Teche Section meeting held May 13 in Lafayette, La., at Don's Seafood Inn. Gus Vogler of Allen Cathodic Protection Co. introduced the speaker.

Mr. Olive illustrated his subject with slides showing actual conditions experienced by his company. He outlined various types of corrosion, factors tending to accelerate corrosion, control of corrosion by cathodic protection and typical examples of corrosion as experienced in drilling operations, gasoline plants and underground flow lines. Following his talk, Mr. Olive answered questions from the floor.

George M. Harper, Jr., of Union Oil Co. of California, section chairman, announced that J. H. Booksh, Jr., United Gas Corp., New Iberia, La., had been appointed secretary-treasurer since J. H. Waterfield, former secretary-treasurer, has been transferred to the Sabine-Neches Section, Lake Charles, La.

## Titanium Welding

Improved methods for welding titanium and other data on titanium were presented June 16 during the titanium session of the American Welding Society's National Spring Meeting at Houston.

## ASTM Meeting

Corrosion matters included in the program for the 56th Annual Meeting of the American Society for Testing Materials at Atlantic City, June 28-July 3 were: Thursday, July 2—Symposium on Porcelain Enamels and Ceramic Coatings as Engineering Materials; Plastics, and a session on corrosion.

## Corrosion Tour Set September 30-Oct. 2

Sufficient interest has been manifested in the 1953 Corrosion Tour to cause Permian Basin Section to decide definitely to hold the tour September 30-October 2 inclusive. John A. Knox, Secretary-treasurer of the section said registrations will be accepted now and that arrangements for field trips, availability of equipment and discussion sessions are well under way.

The tour will be the fourth held under sponsorship of Permian Basin Section. In 1951 the tour was attended by 140. Similar tours were held in 1948 and 1949. Interest in the event is widespread and registrants come from as far away as New York and California.

The program usually involves the arrangements of a series of field trips. Transportation to the field is provided by chartered bus and discussion sessions usually follow the inspections.

Persons interested in attending the tour are invited to write to John A. Knox, Secretary-treasurer Permian Basin Section NACE, Box 310, Midland, Texas.

At the May 11 meeting of the Permian Basin Section, held in Odessa, the steering committee of the corrosion tour to be held this fall announced the selection of their various committee members and an outline of the plans for the tour. Members saw the film, "Corrosion in Action," produced by the International Nickel Co. which showed the mechanism of corrosion of some metals and alloys.

The steering committee is composed of Lamar Sudduth, Stanolind Oil and Gas Co., John Watts, Humble Pipe Line Co. and E. O. Kemper, Permian Enterprises, Inc.

## C. F. Ward Is New Corpus Christi Chairman

New officers for the Corpus Christi Section have been announced. C. F. Ward, Magnolia Petroleum Co., was elected chairman; John P. Westervelt, Pontiac Pipe Line and Export Co., vice-chairman and Ray Pfrehm, Humble Pipe Line Co., secretary-treasurer. Regular meeting date for the section is the fourth Tuesday of each month.

At the May 26 meeting members heard K. K. Kirwan of the Centriline Corp., New York, N. Y., speak on "Cement Mortar Lining of Pipe Lines in Place." There were 17 members and eight guests in attendance.

## Shreveport Section

"Selected Topics in Cathodic Protection," by G. L. Doremus was the talk scheduled for the June 16 meeting of the Shreveport Section. For the social session, arrangements were made for a cocktail party and a dinner at the Caddo Hotel.

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In March, 1953 there were more NACE members in Texas alone than there were in the whole United States at the end of 1945, second year of the association's existence.

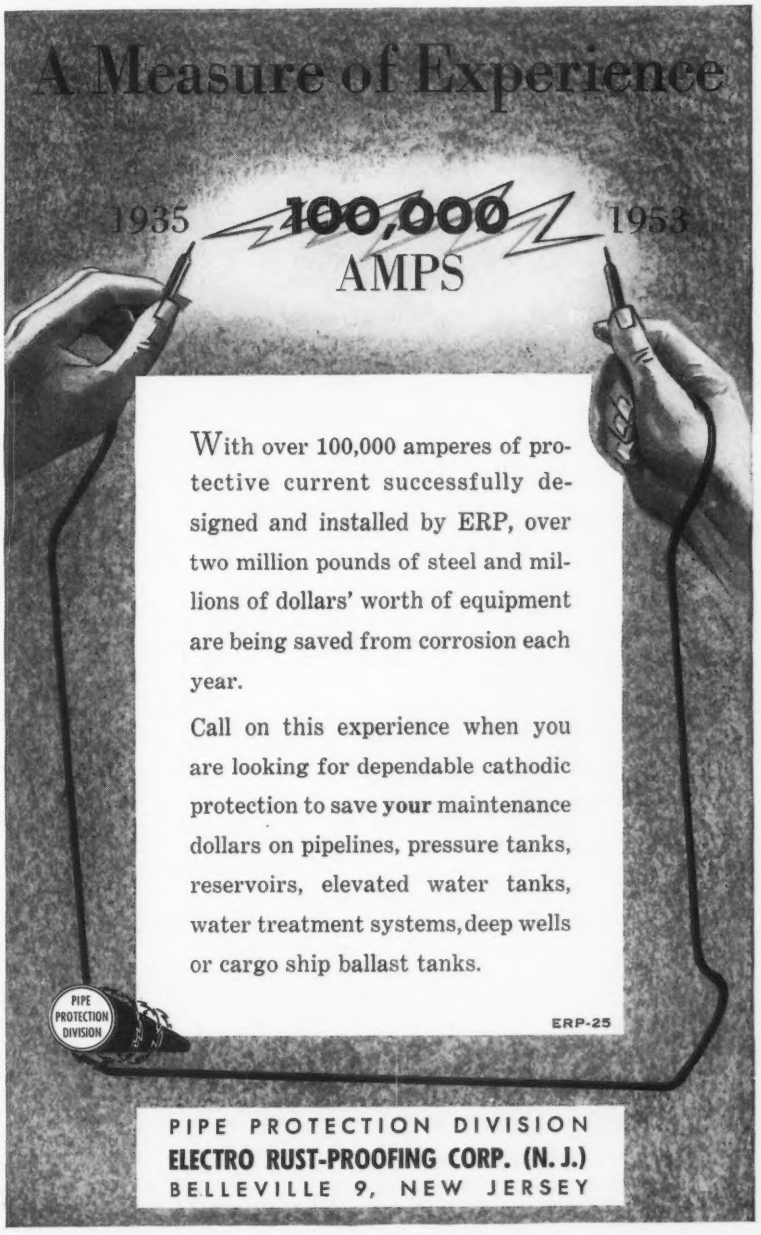
## NACE Sponsors Symposium For Europeans Probing Corrosion Control Methods

A symposium and conference on corrosion control methods in the petrochemical and oil refining fields will be attended by 23 foreign engineers and scientists in Houston July 8. The National Association of Corrosion Engineers is sponsoring the technical program for that date.

The group also will visit the Dow Chemical Company at Freeport on July 6 and the Phillips Chemical Company at Pasadena on July 7 and other installations in the vicinity of Houston.

The scientists to come to Houston are part of 27 from Western Europe spending a month in the United States investigating preventive maintenance practices developed by chemical and petrochemical industries. The tour is sponsored jointly by the Mutual Security Agency and the Organization for European Economic Cooperation with the objective of helping European plants reduce corrosion and increase efficiency.

The group has visited research laboratories and industrial plants in Boston, Jersey City and Harrison, N. J. and Wrightsville Beach, N. C. In New York City they conferred with corrosion engineers. On June 17 the group divided into three teams of which one will study the heavy chemicals industry, with special attention to corrosion problems in the manufacture of acids, heavy industrial chemicals, plastics and magnesium.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# Los Angeles Hears Raifsnider on Sulfate Bacteria

## *Testing Methods of Control Covered at May 20 Meeting*

Los Angeles Section members, 69 strong, at a meeting May 20, heard Dr. P. J. Raifsnider of the Shell Development Co. give a comprehensive talk on Anerobic Micro Biological Corrosion by Sulfate Reducing Bacteria. Dr. Raifsnider explained the cell structure of the anerobic microorganisms, the things they need to sustain life and the conditions under which they thrive. Ferrous iron and moisture are known to stimulate their growth, he said. The exact mechanism of the corrosion is not known, but it is known that some form of sulfate must be present in the soil or natural waters.

He said cast iron and steel are readily attacked by sulfate reducers. Cast iron is graphitized and steel suffers scattered shallow lake type pitting which sometimes runs together and forms very large pits. The corrosion product is black and has a bumpy appearance. When the crusty black deposit is removed, the metal is covered with a greenish white paste. When the paste is removed the metal is found to be bright, Dr. Raifsnider said.

### Methods of Testing

He explained methods of testing for sulfate reducers in soils, saying that cultures could be used, wet soil treated with hydrochloric acid, or dry soil heated which, if the microorganism is present, will produce a strong odor of sulfides.

A number of failures of oil well casing due to bacteria in the Ventura and Texas oil fields were cited. Usually the corrosion was found at depths of 100 to 400 feet. In each case, sulfate reducers were found in the core samples from the well. Cathodic protection (of rather high current densities, at least at first) will protect wells against sulfate corrosion, as will also circulating a high pH drilling mud. Other remedies are formaldehyde, which appears to be very effective and sodium aresnite which is also effective for a short while, but the bacteria seem to build an immunity to it in a short time. For pipe lines, heavy asphaltic or coal tar coatings plus cathodic protection seems to be the most practical solution.

### Mud Cuts Casing Damage

Dr. Raifsnider received several compliments on his paper. Frank Davie, Shell Oil Co., Los Angeles, confirmed use of high pH mud, saying that since the pH of mud used in the Ventura field had been held at 10 to 10.5, no leaks attributable to sulfate corrosion had been recorded. Dr. Rosenfeld, California Research Corp., La Habra, said his experience was that 60 degrees C seemed to be best for culture growth and asked Dr. Raifsnider if he had used higher temperatures. Dr. Raifsnider said he had held cultures at 90 degrees C and said apparently cultures could live at higher temperatures under pressures sufficient to prevent boiling.

J. F. Dorsey, Southern California Gas Co., Los Angeles, also praised the paper. He cited examples of anerobic corrosion on pipe lines at certain stream crossings in Southern California. As tests for sulfate reducers he recommended a redox probe or use of sodium azide iodine. Use of cultures he thought too slow. At one stream crossing, he amply protected pipe by using both asphaltic coating and cathodic protection. Bare metal samples buried alongside the pipe and electrically connected to it severely corroded even though the pipe did not.

Dr. R. D. Pomeroy, Pomeroy and Associates, Pasadena, congratulated Dr. Raifsnider on his paper. He said an effective method of reducing sulfate in sewers and sewer systems is to load sewers with lime to raise the pH to 12. This kills all bacteria and controls odors at the same time, he said.

## Pi Tau Sigma Award Goes to H. L. O'Brien

H. L. O'Brien, member of NACE and General Conference Chairman of the 1953 Conference, has been awarded the Pi Tau Sigma Gold Medal Award for the year 1952. The award is for outstanding achievement in mechanical engineering within ten years after graduation. It is considered one of the highest tributes paid to the abilities of young engineers in the United States.

Mr. O'Brien is product manager for conservation equipment for the Graver Tank and Manufacturing Co., Inc. He received a BSME from Purdue University in 1946 and holds a master's degree from the same university. After receiving his master's degree he became project engineer for the Pressure Vessel Research Project at Purdue and was on the faculty staff. Shortly before joining Graver he was promoted to assistant professor at Purdue. With Graver he has served as assistant manager of the research and development department and as product sales engineer.

In addition to NACE, Mr. O'Brien is a member of API and ASME. At the last API annual convention he delivered a paper on "Evaporation from Conservation-Type Tanks—A Practical Review."

## San Francisco Section Hears C. G. Munger

"Coatings as Engineering Materials," was the subject of a talk by C. G. Munger, before the San Francisco Bay Area Section meeting held June 3 at the Alouette Restaurant. Mr. Munger discussed the various types of synthetic resins which are in common use as coatings for resistance to various chemicals as well as atmospheric corrosion. He discussed at some length the various fields of application of these several types of coatings and the limitations of each type.

In evaluating the position of these coatings among the materials of engineering, he stressed the importance of surface preparation, of coating adhesion, of coating thickness and of coating uniformity. The contribution of each of these properties to the effectiveness of the finished coating structure was evaluated.

Mr. Munger, who is vice president and technical director of the Amercoat Corp., Southgate, Calif., also discussed a new inorganic type of coating known as the zinc silicate type. He showed a number of slides which demonstrated the type of applications in which this coating had been quite successful. A lively discussion period followed the address. About 50 members and guests attended.

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# Few Key Posts Are Open on Kansas City Program

## Three New Symposia Are Listed by Committee Chairman

Only a few key posts of officials on the technical program for the 1954 NACE Conference and Exhibition at Kansas City remain to be filled. F. L. Whitney, Jr., chairman of the technical program committee reports substantial progress in completing the roster of symposia and discussion leaders and some progress in commitments for technical papers.

The preliminary outline of events on the technical program shows the following symposia which are new: Corrosion by Atmospheric Pollutants, Cost of Corrosion, and Non-Destructive Testing.

Mr. Whitney also appealed to persons who have technical material suitable for presentation at any of the scheduled symposia or who know of someone who has suitable material to communicate either with the listed symposium chairman or directly with him. Mr. Whitney is especially anxious to get papers likely to produce lively discussion.

Scheduled symposia and officials were named as of June 5 are as follows:

Cathodic Protection Symposium. No chairman named.

Chemical Industry Symposium. Chairman, E. G. Holmberg, Alloy Steel Products Co., Linden, N. J. Co-chairman, W. B. DeLong, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Corrosion by Atmospheric Pollutants. Vance N. Jenkins, Union Oil Co. of Cal., Los Angeles.

Corrosion Principles. Chairman, H. P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont.

Cost of Corrosion. Chairman, F. N. Alquist, The Dow Chemical Co., Midland, Mich.

Elevated Temperature. Chairman, G. A. Fritzlen, Havnes Stellite Division, Union Carbide & Carbon Corp., Kokomo, Ind. Co-chairman, E. N. Skinner, The International Nickel Co., Inc., New York, N. Y.

Non-Destructive Testing. Chairman, S. A. Wenk, Battelle Memorial Institute, Columbus, Ohio.

Oil and Gas Production. Chairman, R. C. Buchan, Humble Oil & Ref. Co., Houston. Co-chairman, E. C. Greco, United Gas Corp., Shreveport, La.

Pipe Line Coatings. Chairman, A. D. Simpson, Jr., United Gas Corp., Houston.

Power and Communication. Chairman, R. M. Lawall, American Telephone & Telegraph Co., Cleveland, Ohio. Co-chairman, L. O. McCormick, Consolidated Gas Electric Light & Power Co., Baltimore.

Protective Coatings. N. K. Senatoroff, Southern Counties Gas Co., Los Angeles. Co-chairman, W. B. Meyer, St. Louis Metallizing Co., St. Louis.

Refinery. Chairman, E. H. Tandy, Standard Oil Co. of Cal., El Segundo.

### Group Discussions

Pipe Line. Chairman, F. I. Dorr, Trunkline Gas Co., Houston.

Pipe Line and Underground Corrosion. No chairman named.

General Corrosion Problems. Chairman, L. E. Stout, Washington University, St. Louis, Mo.

### Educational Lectures

Educational lectures, a feature which proved very popular at the 1953 Chicago Conference will be repeated at Kansas City. R. C. Weast, Case Institute of Technology, Cleveland, Ohio is chairman of this segment of the program.

## Instrument Clinic

The Second Analytical Instrument Clinic will be held at the Eighth National Instrument Conference at Chicago, September 21-25, 1953. Plans announced by Axel H. Peterson, chairman of the analysis Instrument Committee of Instrument Society of America include presentation of eight three-hour lectures and demonstrations six times, morning and afternoon for three days.

**HOUSTON SECTION'S meeting at San Jacinto Inn, restaurant near the battleground of San Jacinto was attended by more than 100. Shown here are Houston Section officers and their wives. From left to right they are Fred W. Gartner, Jr., and Mrs. Gartner, Mr. and Mrs. Dave Hughes, L. G. Sharpe and Mrs. Sharpe, Robert C. Booth and Mrs. Booth and Mr. and Mrs. William A. Wood, Jr. The accordionist is getting close attention from several as he serenades Mrs. Gartner. (Photo by Wayne Broyles.)**

## Summer Meetings for Houston Section Are Favored in Survey

Summer meetings of the Houston Section will be held if tentative plans of section officers materialize. Preliminary checks of the Program Preference Survey which have been returned by section members show that most members favor having the meetings continue through the summer months, according to L. G. Sharpe, Humble Pipe Line Co., chairman. It is likely that the first meeting will be in July, with the June meeting being omitted.

The Program Preference Survey will be used extensively in planning future section activities, according to Chairman Sharpe. Most of the reports have been analyzed and the results will be announced shortly, he said. Results of the survey are available to other sections interested.

## Marine Night Held By British Columbia Section on May 28

To attract new members from the marine industry the recently formed British Columbia section designated their May 28 meeting as "Marine Night." Highlights of the meeting were the two technical papers "Failure of Marine Boiler Tubes" by R. Barer, and "Cathodic Protection for the Prevention of Corrosion on the Underwater Hulls of Ships of the Royal Canadian Navy" by J. A. H. Carson. Both speakers are affiliated with the Pacific Naval Laboratories.

Mr. Carson's descriptions of the success of various applications of cathodic protection in the RCN aroused considerable interest among the members and guests present, most of whom are directly connected with marine affairs.

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## Changes and Additions To TP Committee

Several changes and additions have been made in the organization of the Technical Practices Committee as follows:

TP-1A Pacific Coast. New officers are Frank Davie, Shell Oil Co., Los Angeles, chairman and P. W. Hill, General Petroleum Corp., Los Angeles, vice-chairman.

TP-1K Evaluation of Inhibitors for Use in Oil and Gas Wells. This is a new subcommittee. Officers have been named as follows: J. C. Spalding, Jr., Sun Oil Co., Dallas, and E. C. Greco, United Gas Corp., Shreveport, co-chairmen.

TP-5D Corrosion by Acetic Acid. The title of this committee formerly was Corrosion by Organic Acids and Bases.

TP-6 Protective Coatings, A. J. Liebman, Dravo Corp., Pittsburgh is now chairman. Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa. is co-chairman.

TP-6A Organic Coatings and Linings for Resistance to Chemical Corrosion. New officers are R. McFarland, Jr., Hills-McCanna Co., Chicago, chairman; C. G. Munger, Amercoat Corp., South Gate, Cal., co-chairman.

TP-14A Electrical Holiday Inspection of Coatings. This is a new subcommittee. Lyle R. Sheppard, Shell Pipe Line Corp., Houston is chairman.

TP-16C Cathodic Protection of Cable Sheaths. A co-chairman has been named as follows: J. J. Pokorny, Cleveland Electric Illuminating Co., Cleveland, Ohio.

TP-16D Tests and Surveys. J. C. Howell, Public Service Electric & Gas Co., Maplewood, N. J. has been named co-chairman.

TP-19 Corrosion by Deicing Salts. M. B. Hart, Illinois Bell Telephone Co., Chicago, is new co-chairman.

## TP-19 Meeting Report

A meeting of Technical Practices Committee No. 19—Corrosion by Deicing Salts was held in Chicago during the recent Ninth Annual Conference & Exhibition.

Committee Chairman F. E. Kulman, Consolidated Edison Co. of New York Inc., New York, New York, led a discussion covering several aspects of the committee's work. Notable among these were corrosion of underground cables and transformers and corrosion of above ground structures, the effect of salt concentration on the rate of corrosion, methods of measuring corrosion rate and mitigative measures taken by several large U. S. cities to combat corrosion caused by de-icing salts.

The possibility of submitting a progress report on corrosive effects of deicing salts for publication in CORROSION magazine was discussed also.

## Strip Film on Porcelain

A 60-frame, full-color strip film, "Porcelain Enamel, The Lifetime Materials of a Thousand Uses," and an information script available for presentation at technical meetings has been prepared by The Porcelain Enamel Institute, 1346 Connecticut Ave., N.W., Washington, D. C.

## Sheppard Heads New TP Committee on Coating Inspection

Lyle R. Sheppard, Shell Pipe Line Corp., Houston has been named chairman of Technical Practices Subcommittee 14-A on Electrical Holiday Inspection of Coatings. This subcommittee is a subsidiary of Technical Practices Committee 14 on Instruments for Corrosion Measurements.

Membership of the committee is busy now outlining a course of action to determine precedence among the several possible investigations indicated. Problems include holiday inspection of pipe coatings before burial, after burial and of coatings on tank bottoms. It is possible the committee will elect to investigate first the problem of inspecting pipe coatings before burial, which includes the following points:

1. What types of measuring voltages should be used?
2. What safety hazards are involved?
3. How soon after application should testing be done?
4. How long should testing voltages be applied?
5. What are the wrapper and moisture effects on testing?
6. What values of voltages and amperages (maximum and minimum) should be applied to various types and thicknesses of coatings?

## Zinc Institute Elects

Elected as directors for the American Zinc Institute at the society's meeting held last April were: K. C. Brownell, American Smelting & Refining Co.; E. R. Dondorf, National Lead Co.; R. E. Dwyer, Anaconda Copper Mining Co.; Andrew Fletcher, St. Joseph Lead Co.; G. H. LeFevre, U. S. Smelting, Refining & Mining Co.; W. H. Leverett, National Zinc, Co., Inc.; S. D. Strauss, American Smelting & Refining Co.; Jean Vuillequez, The American Metal Co., Ltd., all of New York, N. Y. and Elmer Isern, Eagle-Picher Co., Miami, Okla. and E. H. Snyder, combined Metals Reduction Co., Salt Lake City, Utah.

## *Caster Is Chairman, Luce Vice-Chairman Of S. W. Ohio Section*

Newly elected officers for the 1953-54 season were announced at the final meeting of the Southwestern Ohio Section meeting held May 26 in Cincinnati, Ohio, at Shullers restaurant. New officers are: Arthur Caster, chairman; Walter Luce, vice-chairman; R. Leonard Wood, treasurer; Lewis M. Lederer, secretary. Elected as trustees were: L. B. Routson, Rex Stephenson, William Strader and Joseph Creevy.

William Shaw and E. R. Johnson of the National Lead Company of Ohio read papers on "Activities at Fernald." The National Lead Company operates the Atomic Energy Commission Feed Materials Center at Fernald, Ohio. There were 17 members and 6 guests at the meeting.

## Pipeline for Coal Is Found Successful

Coal can now be pumped successfully through pipe lines much in the manner as oil and gas are, recent experiments show. A recently published article relates that the Pittsburgh Consolidation Coal Company has been pumping a slurry of pulverized coal mixed with water through a 12-inch pipe for a distance of 17,000 feet. After being discharged, the coal is dried and made ready for burning. The experiment was conducted near Cadiz, Ohio.

The method is expected to be useful in supplying fuel to steam plants burning powdered coal.

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Canadian membership in NACE increased more than 100 percent during 1953.

## ROYCE H. LEROY

Dr. Royce H. Leroy, member of NACE, and a professor of chemistry at Texas A & M College, was killed in a boat explosion on the Neches River near Beaumont, Texas, April 4, 1953. At the time of the accident, Dr. Leroy was doing chemical research for the Texas Gulf Sulphur Co. Observers from Beaumont said an explosion ripped the boat. The hull of the 23-foot craft was found, burned to the water line, near an island. The bodies of Dr. Leroy and his two companions were found nearby. Dr. Leroy had been a member of NACE since 1951.

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An award is made annually by NACE to the author or authors whose paper published in CORROSION is judged best of those published by authors under 35.


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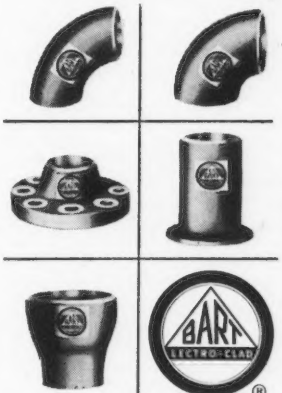

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*Exclusive territories available to qualified distribution organizations.*

## Papers on Corrosion Presented at ASME Los Angeles Meeting

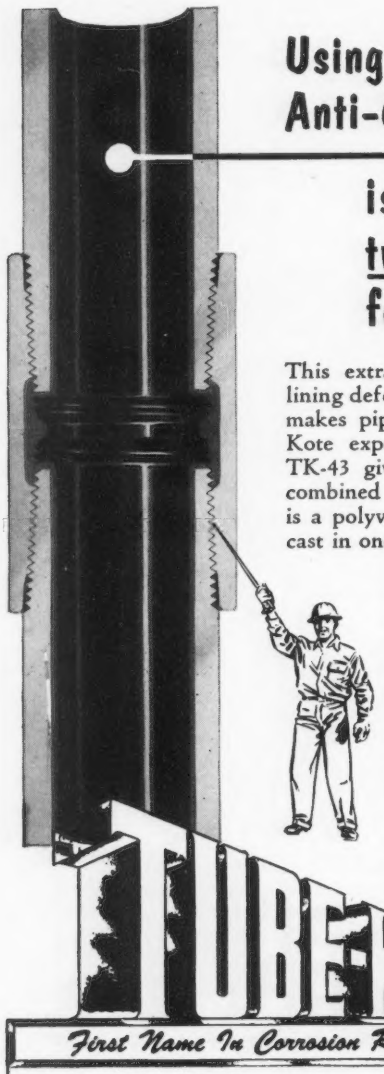
Papers pertaining to corrosion presented during the technical sessions of the semiannual meeting of the American Society of Mechanical Engineers at Los Angeles, June 28-July 2 were:

June 30—Boiler Feedwater Studies I, Power IV. Progress in the Study of Corrosion in the Moisture Region of Large Steam Turbines by Trafford W. Bigger, J. F. Quinlan and C. C. Carson, General Electric Co. Reduction of Condensate Line Corrosion by Scott Jensen and E. Russell Lang, Southern California Edison Co. A Preliminary Investigation of Iron Oxide Deposition in Boiler Feedwater Studies by E. G. Gothberg, Henry Kehmna and E. S. Johnson, Pacific Gas and Electric Co.

July 1—Boiler Feedwater Studies II, Power V. The Mitigation of Marine Fouling by Anaerobic Treatment by H. T. Duplice and R. C. Alexander, Dept. of Water and Power, City of Los Angeles. Zeolite vs Soda Ash in Hot Process Softener at Firestone by W. F. Fields, Firestone Tire & Rubber Co. Recirculation Cooling Water System at Tucson by J. H. Saunders, Tucson Gas, Electric Light and Power Co. Ion-Exchanger Equipment in the Treatment of Boiler Make-up Water by A. A. Lingo, Highgrove Steam Power Co.

Heat Transfer and Fluid Mechanics Institute VI. Formation of Bubbles at Simple Orifices by R. R. Hughes, A. E. Handlos, H. D. Evans and R. L. Maycock, Shell Development Co.

July 2—Heat Transfer and Fluid Mechanics Institute VIII. Present Status of Cavitation Problem by R. T. Knapp, California Institute of Technology.

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## BOOK REVIEWS

**Radiation Suppressing Coatings for Metals at Elevated Temperatures.** By A. H. Sully, E. A. Brandes and R. B. Waterhouse, 7 x 9½ inches, paper, 24 pages. April, 1953. Fulmer Research Institute, Ltd., Stoke Poges, Buckinghamshire, England. Per Copy, 15/

Tests were made to determine what coatings were best suited to reduce temperatures of metals, which must not be heated in excess of 800-900 degrees C, subjected to radiated heat in gas turbines. Several ceramic coatings were tested to determine emissivity characteristics and various methods of bonding coatings were explored. Tests were made to determine the fatique and thermal shock characteristics of the coatings, simulating service conditions. Results indicated certain coatings tested are capable of reflecting a high proportion or incident radiation and can stand a considerable amount of vibration and shock when applied correctly. They can be applied to Nimonic 75 and with a protective enamel undercoat to stainless and mild steel. Coatings of this type are not recommended for parts which normally operate over 600-900 degrees C. Polished metals are excellent reflectors of radiation as long as polish remains. It is not indicated the coatings will protect basis metal against attack by volatile constituents of the fuels, such as vandium or lead compounds.

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**Manual on Industrial Water.** 1953. 6 x 9 inches, cloth. 336 pages plus v. Published January, 1953. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, $4.25.

Intended as a reference source for executives and plant designers, persons involved in industrial operations using water, analysts, operators of special instruments, engineers and consultants, the book is the work of ASTM's Committee D-19. Basic information and direction into technical literature are included. It is expected to be helpful to users of ASTM test methods for industrial water and to those planning for water use at supervisory and investment levels. Much information unassembled elsewhere is collected.

The book provides a critical discussion of important problems in the industrial water field and gives all ASTM Standards. Tests for iron bacteria and sulfate reducing bacteria are included.

Chapter IV—Treatment of Industrial Water covers degasification, chemical treatment, corrosion inhibition.

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Technical material from CORROSION has been reprinted recently in Belgian and British publications.

# Minute Corrosion Losses on Flat Specimens Are Detectable With Interferometer*

AN INTERFEROMETER procedure is being used at the National Bureau of Standards for studies of the corrosion resistance of such materials as optical glass, porcelain enamel, quartz and other natural and artificial silicates and various metals. The method is believed to have value for comparing and predicting the chemical durability of various materials. Although interferometers have been widely used in science and industry for such problems as checking the accuracy of block gages, measuring expansion and checking optical "flats," apparently they have been used very little in previous studies of corrosion resistance. With the highly sensitive interferometer method, corrosion to a depth of as little as 1 or 2 ten-millionths of an inch can be detected on optically flat specimens.

In the NBS technique, devised by Robert G. Pike and Donald Hubbard of the bureau's mineral products laboratories, specimens are ground and polished to optical flatness and then immersed to half their depth in the desired corrosive solution. After the desired length of time they are withdrawn, rinsed and dried and covered with an optically flat piece of quartz. Using a conventional interferometric viewing apparatus of the Pulfrich type and with an unfiltered helium lamp for illumination, the displacement of the optical interference fringes at the level-of-solution line of the specimen is observed.

As seen by the observer looking into the eyepiece of the instrument, these interference fringes are vertical parallel lines. If the uniform flatness of the specimen under study has not been impaired by the corrosive solution, these fringes are straight and continuous. However, if the previously-immersed part of the specimen surface has been sensibly attacked, each of the vertical fringes is shifted laterally at the point where it crosses the change-of-thickness line. If as sometimes happens the solution has caused swelling of the specimen, the lateral shift is in the opposite direction. A lateral shift equal to the space between two adjacent fringes corresponds to a dimensional change in the specimen amounting to one-half wavelength of light, or roughly 0.3 micron. (A micron is a millionth of a meter or about 40 millionths of an inch.) With careful use of the interferometer, changes in specimen thickness of as little as 0.003 micron can be detected.

Silicates studied by this procedure at NBS were quartz, fused silica, opal, obsidian, flint and pitchstone. Porcelain enamels studied were acid-resistant, class A; "glass-lined" tank and acid-resistant, class D. Metals were cold-rolled steel, aluminum, copper, brass, silver and platinum. The corrosive agents ranged from concentrated sulfuric acid ($H_2SO_4$) to

Figure 1—Photo of a typical fringe pattern as seen through the eyepiece of the interferometer at NBS. Swelling of the lower half of the specimen—the half that was previously immersed in a corrosive solution—has caused displacement of the fringes (dark vertical bands) to the left. Here the shift amounts to about ¼ fringe. (A shift of 1 fringe indicates a dimensional change in the specimen of about 12 millionths of an inch.)

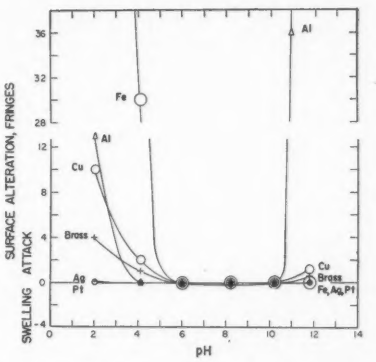


Figure 2—Results of NBS measurements of the chemical durability of certain metals by the interferometric method. Data are for 6 hours' immersion at 80 degrees C in solutions of various degrees of acidity or alkalinity.[1] (Because of the rapid reaction of certain samples, immersions much shorter than 6 hours were sometimes necessary; such data have been extrapolated to the 6-hour basis.) Glass, porcelain enamel and various silicates were similarly investigated at NBS.

5-percent sodium hydroxide (NaOH) solution. Exposure times were as short as one minute and as long as several weeks. Temperature in most cases was held at 80 degrees C.

A number of interesting and sometimes unexpected results were obtained. Swelling of the immersed surface, rather than attack, was found in several cases. For instance, crystalline quartz showed definite swelling after two weeks at 80 degrees C in an acid solution (pH 4.1). Opal-like quartz, a form of silica ($SiO_2$)—showed swelling of nearly 1 fringe of light at pH 2 and continued at a similar level to about pH 8; be-

(Continued on Page 12)

* For further details see An Interferometer Procedure Applied to the Study of the Chemical Durability of Silicates, Enamels and Metals, by Robert G. Pike and Donald Hubbard. *J. Res. NBS*, Vol. 50, 87 (1953) Feb. NBS Research Paper 2394. Also Studies of the Chemical Durability of Glass by an Interferometer Method, by Donald Hubbard and Edgar H. Hamilton. *J. Res. NBS*, Vol. 27, 143 (1941) NBS Res. Paper 1409.

CLEANING, COATING, WRAPPING & RECONDITIONING

★

HOT DOPE

Straight from the Kettle on PIPE PROTECTION

★

By Boyd Mayes

• Got in a long confab recently with one of our top men, mainly about old times and how we'd come a long way together. He's been on the job around 20 years. He worked around to the point of telling about how a competitor had been offering him a "better" job and sort of camping on his trail about the proposition until he found he couldn't meet the "traffic." This man, like most of our skilled craftsmen, is pretty well aware of the fact that pipe conditioning outfits these days hatch out fast but that their mortality rate is high . . . especially if the shingle they hang up is a lot bigger than the bin they're eating out of. I can tell you I was mighty pleased about my man's attitude. After all I know from my East Texas piney-woods experience, that it's pretty hard to smoke a coon out of a well-stocked hole!

★

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## Hot Dip Galvanizing Folder Is Published

"Recommendations for the Proper Preparation of Materials Prior to Hot Dip Galvanizing," a four-page, 8½ x 11-inch folder, has just been published by the American Hot Dip Galvanizers Association, Inc. The folder illustrates and discusses the proper design and fabrication of a wide variety of products prior to hot dip galvanizing. The new folder is available free from the Association offices, 1507 F First National Bank Bldg., Pittsburgh 22, Pa.

## Minute Corrosion—

(Continued from Page 11)

tween pH 8 and pH 11, however, the swelling changed rapidly to an attack of 3½ fringes. Although brass was attacked by strongly acid and strongly alkaline solutions, there was a slight indication of swelling in the more nearly neutral solutions. Such apparent swelling could perhaps be caused by the formation of a layer of insoluble salt having greater volume than the metal from which it was formed. Of the metals studied, only platinum showed no detectable dimensional change under the laboratory conditions. The three types of porcelain enamels studied varied widely in their chemical inertness as indicated by the test.

•

NACE's 10th Annual Conference and Exhibition will be held at Kansas City March 15-19, 1954.

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# *Continuous Record of Changes in Weight Electromechanically Made by Device**

AN ANALYTICAL balance recently developed at the National Bureau of Standards automatically makes a continuous record of changes in weight, following even rapid changes with good accuracy. Developed by Floyd A. Mauer of the NBS mineral products laboratory, the new instrument is being used at the bureau to record changes in weight of samples of complex minerals during thermal decomposition. Because it combines versatility and convenience with low cost, the device is suitable for many other laboratory applications requiring a record of weight as a function of time.

The NBS instrument uses a conventional laboratory balance modified so that changes of weight are balanced by adjustment of a magnetizing current. The balancing force results from the interaction of the magnetic field of a solenoid (coil of wire) with the field of a permanent bar magnet suspended, inside the solenoid, from one side of the balance. Automatic balancing is achieved by means of a photoelectric sensing arrangement in which a beam of light is reflected to a dual phototube from a mirror mounted on the balance beam. The two sections of the phototube are connected in a bridge circuit, the output of which is amplified and applied to the solenoid. Any change in weight tending to produce unbalance is promptly counteracted by whatever change of solenoid current is needed to maintain balance (within a small fraction of a division of the balance scale). An electronic damping circuit eliminates oscillations and enables the electrical output of the instrument to faithfully follow very rapid changes of weight.

The record of weight changes is obtained by connecting a resistor in series with the solenoid and applying the voltage developed across this resistor to a commercial recording potentiometer of the strip-chart type. Since the balancing force exerted on the magnet is directly proportional to the current through the solenoid, the weight scale is linear and the recorder is easily made to read directly in milligrams. By substituting a different dropping resistor, a different magnet, or both, full scale ranges of as little as 10 milligrams or as much as 1 gram are obtained. For ranges of 100 milligrams or more, accuracy is better than ½ of 1 percent of full scale.

The electronic circuitry of the balance is quite simple. In addition to the phototube, the entire tube complement consists of two twin-triode amplifiers, a power-supply rectifier and three voltage regulators. When the two sections of the phototube are equally illuminated, the output of the bridge circuit in which they are connected is zero. Any movement of the balance beam results in a bridge output voltage that is proportional to the departure of the beam from its equilibrium position.

If this voltage is amplified and applied to the solenoid without any provision for damping, the balance tends to oscillate around the equilibrium position. To eliminate this oscillation both magnetic and viscous damping were tried successfully, but a simple modification of the electronic circuit to provide velocity damping proved far more convenient. This velocity-damping circuit, a type commonly used in servo systems, senses the rate at which the unbalance signal is changing (this rate is proportional to the velocity of the balance beam) and applies to the solenoid a component of current that is proportional to this rate. This current is phased so as to oppose the motion of the beam. The result is a braking force, proportional to the velocity of the beam, that can be adjusted to eliminate the tendency of the beam to oscillate. When the damping control is properly adjusted, an abrupt change in weight as great as 1 gram can be recorded in 3 seconds without excessive hunting.

The balance has been used at the bureau to provide thermochemical data for a study of the kinetics of the dehydration reaction of kaolins. This weighing technique has proved ideally suited to the automatic recording of both weight-change and differential temperature

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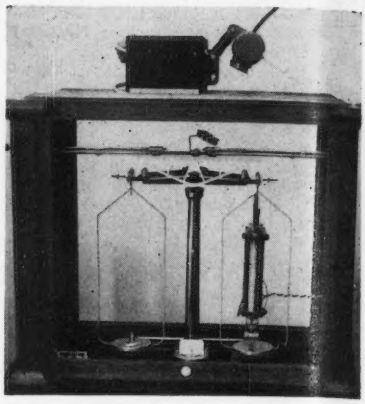

**Figure 1—Close-up of the modified laboratory balance that is the heart of the recording instrument. In the work for which the new instrument is being used at the bureau, specimens are suspended from the left-hand balance tray into a small electric furnace under the table that supports the balance. While the specimen is being heated, its weight is recorded continuously.**

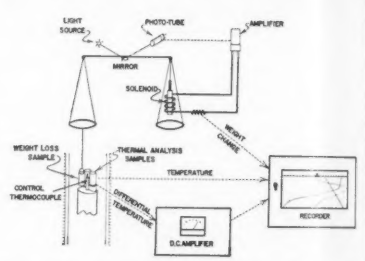


**Figure 2—Diagram showing how the NBS balance is used to record changes in the weight of a mineral sample on the same chart with its differential temperature curve.**

* From information supplied by National Bureau of Standards, Washington, D. C.

# Complete Information Is Given on Cathodic Protection Short Course

Theory and practice in corrosion will be discussed at the Short Course on Cathodic Protection to be held at the University of Illinois, October 12-16. The National Association of Corrosion Engineers is co-sponsoring the course and all instructors are active members of NACE.

Co-ordinator for the course is Professor Ray Wainwright, associate professor of electrical engineering at the university. Speaker for the banquet to be held October 15 at the Urbana-Lincoln hotel will be Robert B. Mears, manager of research and development laboratories of the United States Steel Corp. His address is titled: "The Next Fifty Years."

Instructors for the course will be: Norman Hackerman, professor of chemistry and director of the Corrosion Research Laboratory, the University of Texas; Ray M. Wainwright, associate professor of electrical engineering at the University of Illinois; Lyle R. Sheppard, corrosion research engineer, the Shell Pipe Line Corp.; Mathew G. Markle, chief gas engineer, the Public Service Division, Commonwealth Edison Co.; Marshall E. Parker, consulting corrosion engineer and owner of the Cormit Engineering Corp. and Harold N. Hayward, associate professor of electrical engineering; director, measurement program, Engineering Experiment Station, University of Illinois.

Attendance at the course will be limited to 50 persons. Cost will be $47.50, payable to the university. This includes a fee of $37.50 for lectures, laboratories and demonstrations and a charge of $10 for five luncheons and the banquet. It also includes dittoed notes from the lectures and a notebook to hold them.

### Reservations for Rooms

Reservations for hotel accommodations must be made in advance. Blocks of reservations will be made at local hotels or motels starting on Sunday evening (Oct. 11) and ending Thursday evening or Friday afternoon (Oct. 15-16). Single room prices will range from $5 to $8 per person; double occupancy, $6 and up. Good rooms accommodating four or five persons to the room are available at a new motel for about $4 to $5 per person.

Short Course lectures will be 50 minutes. Unoccupied hours are intended for conferences, discussions and inspection trips as desired.

Arrangements for luncheons have been made with a special cafe in the Illini Union, on the campus, meals to be served at noon, Monday through Friday. Admission to these luncheons will be by ticket only.

NACE will have a representative present throughout the course to take memberships. A membership costs $7.50 and includes a year's subscription to CORROSION, NACE monthly publication. Further information on the course may be obtained by writing Ray M. Wainwright, Electrical Engineering Department, University of Illinois, Urbana, Ill. A schedule showing subject and time of class meeting follows:

### Tentative Program

**Monday, October 12**

9-11 am Registration

11-11:50 am Address of Welcome

1-2 pm Principles of Electrochemistry for Corrosion Engineers. Instructor, Norman Hackerman, topic: Basic Electrochemistry.

3-5 pm Review of Electric Circuit Theory. Instructor, Ray M. Wainwright, lecture.

**Tuesday, October 13**

8-9 am Corrosion Engineering. Instructor Lyle R. Sheppard, topic: Materials.

9-10 am Economics and Management Problems in Corrosion and Cathodic Protection. Instructor, Ray M. Wainwright, topic: Mathematics of Finance.

10-11 am Design and Application of Cathodic Protection Systems. Instructor, Marshall E. Parker, topic: Rectifiers and Ground Beds.

1-2 pm Principles of Electrochemistry for Corrosion Engineers. Instructor, Norman Hackerman, topic: Basic Electrochemistry.

2-3 pm Instruments and Measurement Techniques for Corrosion and Cathodic Protection. Instructor H. N. Hayward, topic: Basic Theory.

3-4 pm Laboratory. Instructors, Ray M. Wainwright, H. N. Hayward and Staff, topic: Field Testing Practices.

**Wednesday, October 14**

8-9 am Corrosion Engineering. Instructor, Lyle R. Sheppard, topic: Coatings.

9-10 am Economics and Management Problems in Corrosion and Cathodic Protection. Instructor, Ray M. Wainwright, topic: Mathematics of Finance.

10-11 am Design and Application of Cathodic Protection Systems. Instructor, Marshall E. Parker, topic: Rectifiers and Ground Beds.

1-2 pm Principles of Electrochemistry for Corrosion Engineers. Instructor, Norman Hackerman, topic: Basic Electrochemistry.

2-3 pm Instruments and Measurement Techniques for Corrosion and Cathodic Protection. Instructor, H. N. Hayward, topic: Basic Theory.

3-4 pm Laboratory. Instructors, Ray M. Wainwright, H. N. Hayward and Staff, topic: Field Testing Practices.

8 pm Movies on Corrosion.

**Thursday, October 15**

8-9 am Corrosion Engineering. Instructor, Lyle R. Sheppard, topic: Tests and Inspections.

9-10 am Economics and Management Problems in Corrosion and Cathodic Protection. Instructor, Ray M. Wainwright, topic: Economic Analysis of Cathodic Protection Systems.

10-11 am Design and Application of Cathodic Protection Systems. Instructor, Marshall E. Parker, topic: Sacrificial Anode Systems.

1-2 pm Principles of Electrochemistry for Corrosion Engineers. Instructor, Norman Hackerman, topic: Polarization and Overvoltage.

2-3 pm Instruments and Measurement Techniques for Corrosion and Cathodic Protection. Instructor, H. N. Hayward, topic: Survey of Corrosion Instruments.

3-4 pm Laboratory. Instructors Ray M. Wainwright, H. N. Hayward and Staff, topic: Field Testing Practices.

7 pm Banquet.

**Friday, October 16**

8-9 am Corrosion Engineering. Instructor, Lyle R. Sheppard, topic: Planning and Reports.

9-10 am Economics and Management Problems in Corrosion and Cathodic Protection. Instructor, Mathew G. Markle, topic: Personnel and Organization; Management Selling.

10-11 am Design and Application of Cathodic Protection Systems. Instructor, Marshall E. Parker, topic: Sacrificial Anode Systems.

1-2 pm Instruments and Measurement Techniques for Corrosion and Cathodic Protection. Instructor, H. N. Hayward, topic: Techniques of Cathodic Protection Testing.

2-4 pm Round Table Discussion by staff of instructors.

## Continuous Record—

(Continued from Page 12)

curves on a single chart and has made it possible to obtain large amounts of needed data with a minimum of attention from laboratory personnel.

An example of a potential application of the NBS recording balance is in the drying of cotton fibers, or other moisture absorbent material, to constant weight. A commercial manufacturer of instruments has already indicated an interest in constructing a model of the NBS instrument tailored to this particular use. Another contemplated use is in the study of the high-temperature oxidation resistance of certain of the cermets that are now being tried as turbine blade materials.

## MANUSCRIPTS approved for Publication IN CORROSION

**Fundamental Concepts of Electrode Potentials by Andre J. de Bethune.**

**Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures by F. H. Beck and M. G. Fontana.**

**All-Plastic Materials of Construction for Corrosive Environments by J. L. Huscher.**

**Corrosion Resistance of Beryllium Copper—A Survey by J. T. Richards.**

**Filiform Corrosion by M. Van Loo, D. D. Laiderman and R. R. Bruhn.**

**Cathodic Protection of Active Ships in Sea Water with Graphite Anodes by K. N. Barnard, G. L. Christie and J. H. Greenblatt.**

**Accelerating Effect of Decreasing Temperature on Corrosion by Glycol Solutions by D. Caplan and M. Cohen.**

**Electrical Treatment of Boiler Feed Waters by T. F. Hurley, H. Ingleson, W. J. Sparks and R. Wilkinson.**

# NEW PRODUCTS —Materials—Service—Literature

**Isotope Products Limited,** Box 127, Oakville, Ont., Canada has published a list of isotopes, their half-life, the type radiation produced, and what the isotopes are used for. For corrosion research, iridium 192 is used. It has a half life of 70 days. Cobalt 60 is used for oil pipe line tracing. It has a half life of 5.3 years. The isotope with the shortest half life is polomium 212, two and one-half millionths of a second. The longest lived isotope is uranium 238 with a half life of 50,000,000 years.

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**Lamar Pipe and Tile Co.,** 2416 Hess St., Saginaw, Mich. has developed a novel method of laying pipe underground without disturbing the surface. The new, "Tunneliner" pipe is made in short, precast, elliptical sections with a ratio of length to width permitting one section to be passed through the portion of underground sewer already tunneled. The installation process requires less earth removal than with old methods and fewer one-the-job laborers are needed. Only simple standard skills are required and less installation equipment is necessary. The finished sewer is stronger and has a slightly larger capacity than if built with circular pipe of the same nominal diameter. Financial control of Lamar Pipe and Tile Co. has been recently acquired by American-Marietta Co., of Chicago, Ill.

•

**Bakelite Company,** a division of Union Carbide and Carbon Corp., 260 Madison Ave., New York, N. Y. has announced plans for what it calls the "largest single expansion program in the entire history of the plastics industry." Completion of three new plants in 1955 will double present U. S. polyethylene production, bringing total annual production of Bakelite polyethylene to over 250,000,000 pounds. The plants will be located near major gas supplies in Texas and California, since they depend solely on gas for their chemical raw materials.

•

**The American Agile Corp.,** Box 168, Bedford, Ohio, has developed tanks for processing corrosive substances. The tanks are fabricated throughout from unplasticized polyvinyl chloride, a thermoplastic material used in industrial applications where corrosion presents a major problem. The tanks are mainly of welded construction, entirely self-supporting and offer resistance to corrosion on the interior as well as the exterior of the tank. Resistant to most mineral acids, alkalies, inorganic salts and a large number of organic compounds at temperatures up to 170° F., they are built to customer's specifications. They are light in weight with good structural strength.

•

**United Chromium,** Inc., 100 E. 42nd St., New York, N. Y. has developed "Ucilon 454," an air-drying modified vinyl coating that provides a film three to five times thicker than conventional air-drying vinyls. The product was introduced at the National Association of Corrosion Engineers 1953 Conference and Exhibition. The coating resists acids, alkalies, salts, water, and is especially recommended to protect equipment against petroleum and its derivatives. The product has good adhesive qualities and in some cases can be applied directly over rusted and scaled surfaces.

•

**Monsanto Chemical Company** is planning multi-million dollar facilities for the production of isocyanates, according to an announcement by J. L. Christian, vice president and general manager of the company's phosphate division. Mr. Christian pointed out that the steadily increasing number of marketable products in which isocyanates are an essential component, was a major influence in the decision to construct the new plant facilities.

•

**"Fogitron,"** a system for controlling air pollution is being marketed by Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale (Detroit 20), Mich. The company says the equipment is based on the discovery that if water is sufficiently finely divided (as fog) then, in a suitably designed scrubbing tower, this water possesses the ability to "wet" air contaminants. High liquid pressures are used in handling gases, aerosols, fumes, sub-micron dusts, non-water solubles and inflammable dusts. Low liquid pressures are for chemical sprays, dusts over 10 microns, heat transfer and processing, it is stated.

•

**The Conneaut Rubber & Plastics Co.,** Tallmadge, Ohio, has issued a new bulletin, CR-53, on "Conneaut Custom Extrusions." The four-page, two-color bulletin describes in detail the plastics compounding and extruding service made for the manufacturing and fabricating industries. Information is also included on the physical, chemical and dielectric characteristics of polyethylenes and vinyls and how these plastics are specially compounded to obtain a wide range of properties.

•

**"Facts You Shold Know About Plastic Pipe"** is the title of an 8-page brochure published by Waljohn Plastics, Inc., 437 Eighty-eight St., Brooklyn 9, N. Y., to describe the firm's Tenite II, polyethlene, polyvinyl chloride and other plastics. The brochure lists as uses for their pipe, crude oil lines, salt water lines, natural gas lines and many other installations in production, refining and distribution of petroleum products and the company maintains it is excellent for combatting corrosion problems and paraffin deposits. In the chemical industry, the pipe will handle many types of corrosive liquids, gases, chemical and air lines. It may be used also as electrical conduit where corrosive gases may destroy metal conduit. Many other uses are given.

•

**Connecticut Coatings, Inc.,** 45 E. Putnam Ave., Greenwich, Conn., is advertising a surface coating "formulated to provide maximum chemical resistance to many of the corrosive conditions found in industry." The easy-to-apply coatings are known as epoxy-resin-base coatings. They are said to have good adhesion, flexibility, chemical and solvent resistance, toughness and abrasion resistance. They may be applied without primer on ferrous and non-ferrous metals, wood, concrete and paper by brush, dip or spray. Principal uses are in plant maintenance and as industrial finishes with many end use applications.

•

**Sub-Zero Products Co.,** Cincinnati 29, Ohio manufacture low temperature chilling machines designed especially for cold testing. Cubic capacity of models ranges from 1.5 to 4 cubic feet, and in a temperature range from —10° F to —120° F. An advantage the company claims for its model is that it occupies only 7.5 square feet of floor space. Frost-clear observation windows, entrance ports and internal ilumination are provided.

•

**Surveys, Inc.,** 219 Euclid Ave., Trenton 9, N. J. is distributing a bulletin describing an anti-weld and anti-seize thread coating for temperatures to 1500° F. The product is used by manufacturers of jet engines, gas and steam turbines, Diesel engines and operators of stationary or mobile units. It is said the product prevents frozen thread assemblies and does not suffer decomposition.

•

**Calgon, Inc.,** subsidiary of Hagan Corp., Hagan Bldg., Pittsburgh, Pa., have published a folder on the use of their product, "Zeotone," a product designed to clean and "tone up" the zeolite or resin bed in commercial or industrial water softeners. The product in addition to loosening iron deposits, silt and other material that becomes trapped in the softener bed also inhibits rust to protect the metal in contact with the salt solution, the announcement states.

•

**"Ospho,"** a metal primer to be applied directly over rusted surfaces, is manufactured by The Rusticide Products Co., 3125 Perkins Ave., Cleveland 14, Ohio. It is stated that the primer causes iron oxide (rust), to chemically change to iron phosphate. When dry, rust action is stopped and the subsequent paint coating attaches itself so tightly that moisture and oxygen cannot attack the metal, the company maintained.

•

**Reference Book** on Instruments for Electrolysis, Corrosion and Cathodic Protection Testing, issued by the American Gas Association, 420 Lexington Ave., New York, N. Y. in March 1951 is available at $1.50 a copy. Text and diagram descriptions are given of electrical instruments, high voltage coating inspection, locating faults in buried pipe, several types of meters, pH measurement of soils and water, the "Nipple-and-Can" test for soil corrosivity. Commercial catalog sections are included on voltmeters, combination test sets, earth-resistivity meters, pipe locators, holiday detectors, reference electrodes and other equipment.

•

**Unique New Stainless** Alloy Products for the Oil and Chemical Industries, a brochure available from Solar Aircraft Co., 2200 Pacific Highway, San Diego

(Continued on Page 15)

## NEW PRODUCTS

(Continued from Page 14)

12, Cal., describes stainless alloy expansion joints, stainless alloy portable gas turbine power plants from 50 to 500 horsepower, high temperature ceramic coatings and stainless alloy shell mold castings. The hand-started gas turbines are used to drive water pumps and electrical generators.

•

**Agilide Exhaust Ventilators,** made entirely from unplasticized polyvinyl chloride are resistant to most corrosive vapors including nitrous. The fans, supplied in capacities from 250 to 1670 cfm are of fully welded construction, come complete with motor and motor base for incorporation into new or existing systems. Complete specifications are available from American Agile Corp., P. O. Box 168, Bedford, Ohio.

•

**Cambridge Applied Research, Inc.,** 60 White St., Belmont 79, Mass. an independent industrial laboratory welcomes inquiries into its facilities and available services.

•

**Pure Silicon**—at $430 a pound—a brittle, gray sparkling element with crystalline appearance is being produced by E. I. DuPont de Nemours & Co., Inc. The element is finding increasing use in transistors as an alternate to germanium and in rectifiers as an alternate to selenium. In some cases silicon is superior to germanium in transistors especially where temperatures of more than 170 degrees F are involved. The superior heat resistance of silicon is expected to improve the efficiency of rectifiers and effect other improvements in performance.

•

**Teflon** now is being molded in varying wall thicknesses, tapers and undercuts formerly thought impossible by Sparta Heat Treat Co., Plastics Division, East Sparta, Ohio. Production molded diaphragms, washers, discs, seals and cups ends are being produced.

•

**An Improved** glass fiber translucent building panel is being made by International Glass Corp., Puente, Cal. The new building sheet contains over 50 percent glass fibers.

•

**Carpenter Stainless No. 3** (Type 433) is described in detail in a folder now available to steel users from Carpenter Steel Co., Reading, Pa. The stainless, which has excellent corrosion resistance, high resistance to scaling conditions, and low annealing temperature, besides other desirable characteristics, is recommended to replace 18-8, now restricted by government regulations.

•

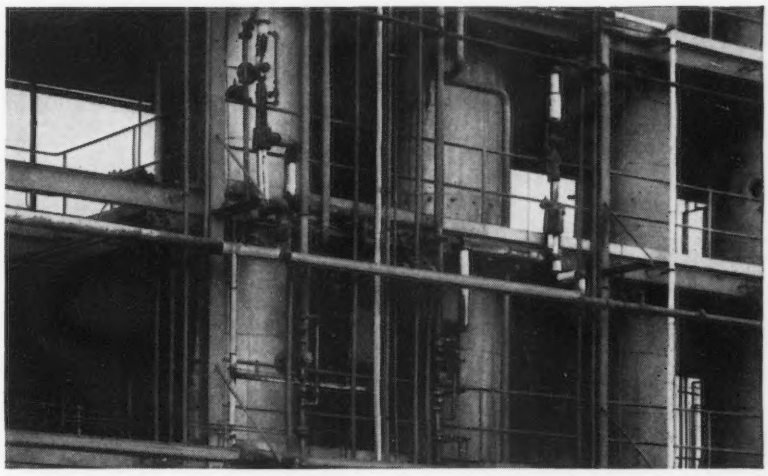
**Stainless Bars,** a 28-page booklet available on request from Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa. covers technical data on stainless steel bars available from Allegheny. Information includes analyses and properties, corrosion resistance of steels to various media, machining data, suggested applications, fabrication properties and techniques and other useful information.

(Continued on Page 16)

DOW

# ETHYL BENZENE REACTORS LINED WITH CORROSION-RESISTANT SARAN RUBBER

**Another example of how SARAN RUBBER tank lining helps cut cost of handling, storing or transporting corrosives**



The ethyl benzene reactors pictured here have a saran rubber lining under one course of chemical brick. The reactors handle ⅓ ethyl benzene, ⅓ higher benzenes, ⅓ benzene and .3% hydrochloric acid. They have been in service for over three years without appreciable effect on the saran rubber lining in spite of the fact that they operate at a temperature of 110° C.

Saran rubber's high degree of chemical and abrasive resistance makes it the ideal lining for tank cars, storage tanks, tank trailers, processing tanks and other equipment handling corrosive acids, solvents, and other chemicals.

Saran rubber lining can be applied easily and economically by experienced saran rubber applicators located strategically throughout the country. We will be glad to advise you as to where and how saran rubber lining can be applied to your best advantage. Get in touch with your nearest Saran Lined Pipe Company office or write direct to The Saran Lined Pipe Company, 2415 Burdette Avenue, Ferndale, Michigan. Offices in New York • Boston • Pittsburgh • Tulsa • Philadelphia • Chicago Portland • Indianapolis • San Francisco Houston • Denver • Los Angeles • Seattle Cleveland • Charleston, S. C. • Toronto Montreal.

**Saran Lined Pipe Company**
**2415 Burdette Avenue, Ferndale, Michigan**

**Please send me your catalog on Saran Rubber Tank Lining and Saran Rubber Molding Stocks.**

Name_____ Title_____

Company_____

Address_____

City_____ State_____

RELATED PRODUCTS

Saran rubber molded parts — stoppers, diaphragms, various-sized moldings for valves, instruments, etc.

Saran lined steel pipe—corrosion-resistant pipe that gives long-term operation with minimum maintenance costs.

*you can depend on DOW PLASTICS*

DOW

## NEW PRODUCTS

(Continued from Page 15)

**Beryllium-Copper** jaw inserts are provided in a light weight aluminum alloy, non-sparking pipe wrench made by Ampco Metal Inc., Milwaukee, Wis. Its tensile strength is comparable to that of a steel tool. It weighs from 15 ounces for the 10-inch size to only 128 ounces for the 36-inch size. Jaw inserts of steel may be used also.

•

**Glass, Aluminum** and porcelain enamel are being used extensively in the construction of the 455-room, 16-story Statler Hotel in Hartford, Conn. The structure will resemble the United Nations building exteriorly.

•

**An Alkali Aluminum** cleaning compound that will not etch or color aluminum yet will clean thoroughly in a spray wash has been perfected by the Van Stratten Chemical Company. A non-toxic and non-flammable material, the cleaner also is said by the company to prevent rusting of ferrous parts after washing. It is said to be safe for use on zinc, brass, copper and bronze. The trade name is Vantrol 5541.

•

**Structural Plastic** doors and an all plastic corrugated lining are used in a refrigerated truck trailer developed by Strick Company, Philadelphia. The new construction, besides having 25 percent better thermal efficiency, makes a weight saving of 1000 pounds over conventional design, manufacturers say. A polyester fiber glass laminate is used inside. The doors are molded in one piece of structural plastic.

•

**Permadizing,** a technique whereby aluminum may be bonded to various compounds of rubber, synthetic rubber or silicone, has been developed by Stillman Rubber Co., 5811 Marilyn Ave., Culver City, Cal. Dimensional tolerances can be held to as fine as 5 micro-finish, the company claims. The covered parts can be made corrosion resistant.

•

**Electrical Circuits** exposed to corrosives can be protected by a new liquid-tight flexible conduit fitting developed by The Thomas Betts Co., Elizabeth, N. J.

•

**RTS 200,** a rosin core solder available from Federated Metals Division, American Smelting & Ref. Co., 120 Broadway, New York City is described in Bulletin 158.

•

**Rue K. Elston Co.,** 2397 University Ave., St. Paul, Minn. manufactures coolers for truck and truck trailer refrigerated bodies using dry ice as a coolant. The units, powered by the trucks' electrical system, are controlled thermostatically to maintain a specified temperature inside the body. The carbon dioxide is exhausted to the air.

•

**Lucoflex** nameplates for machinery identification, because of their exceptional resistance to corrosives retain their legibility over longer periods than some metal nameplates, American Lucoflex, Inc., New York, asserts.

•

**Nukem Corrosion Proof Linings,** a booklet available from Nukem Products Corp., Buffalo 20, N. Y., describes the company's Koroseal, Nuran rubber, neoprene and rubber linings and acid brick sheathings. Copies are available on request.

•

**Nelsonite C3,** an impregnator designed to stop leakage of gases through metal castings is available from Nelsonite Chemical Products, Inc., 900 Monroe Ave., N. W., Grand Rapids 2, Mich. Its slow oxidation rate makes it a fine rust and corrosion preventive, the company says.

•

**For Zinc Dust,** Too, It's Federated First, a bulletin issued by Federated Metals Div., American Smelting & Ref. Co., 120 Broadway, N. Y. C. describes the common applications of zinc dust.

•

**Continuous Plastic** coatings may be applied now to such items as flexible steel tubing, metal and paper jacketed tubing and other hard to coat materials. Pyramid Plastics, Inc., 554 W. Polk St., Chicago 7, Ill. says the coating does not reduce flexibility and the coating material will not penetrate small openings.

•

**Rust-Cutter,** a rust penetrating oil, is supplied in a Freon-charged 6-ounce aerosol can by James R. Kearney Corp., 4236 Clayton Ave., St. Louis 10, Mo.

•

**Lindol HF,** a flame-resistant hydraulic fluid produced by Chemical Division, Celanese Corp. of America, 180 Madison Ave., New York, N. Y. is said by the manufacturer to be inert in the presence of common metals and alloys. The material, tricesyl phosphate, is stable, odorless and non-corrosive.

•

**Murphy & Miller, Inc.,** 1326 South Michigan Ave., Chicago, Ill. is manufacturing a test chamber with a temperature range from —130 degrees F to plus 200 degrees F and a standard humidity cycle of 20 percent to 95 percent from plus 35 degrees F to plus 185 degrees F. It is made with test spaces ranging from 4 to 36 cubic feet. Test spaces are stainless steel with welded seams fitted with 5/8-inch ID sleeved openings for introduction of electrical leads, hydraulic lines, etc.

•

**Swagelok Cap** and Swagelok Plug have been added to the line of fittings made by Crawford Fitting Co., 884 East 140 St., Cleveland 10, Ohio. They are available in aluminum, steel, brass, stainless steel and Monel.

•

**Cooper Alloy** Foundry Company, Hillside, N. J. through an affiliation with Vanton Pump Corp., will extend its product line to include plastic pumps, valves, accessories and fittings.

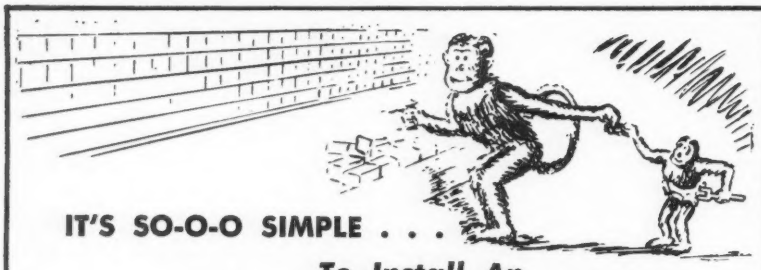
•

**Rectangular** completely assembled glassed-steel fermentation vats are being supplied the brewery industry by The Pfaudler Co., Rochester. The vats will replace conventional round vats to provide more proceessing capacity in the same space.

•

**DeVilbiss Company,** Toledo 1, Ohio has scheduled week-long tuition-free courses

(Continued on Page 18)

IT'S SO-O-O SIMPLE . . .

To Install An

INSULATED GASKET UNION

The Insulator You Have Been Searching For!

- Metal to Metal Threads
- Perfect Electrical Insulation
- 300# W. O. G.
- Will Not Break
- All Insulating Parts in Compression
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SERVICE ENGINEERS, INC.

Manufacturers of Industrial Plastic Products

3030 W. Pafford P. O. Box 11068 Fort Worth 9, Texas

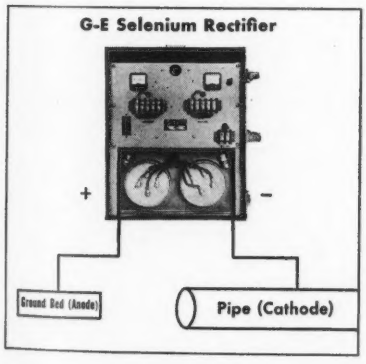
# CATHODIC PROTECTION RECTIFIERS

# Prevent Costly Pipeline Corrosion

Pipelines—and other underground metal surfaces—are constantly subject to destructive galvanic corrosion.

This condition occurs under all uncontrolled circumstances, depending upon soil conductivity, moisture content, dissolved oxygen content, temperatures, protective coatings, dissimilar metals, position of other metallic structures, stray currents, etc. The way to prevent this costly damage to your underground equipment, is to counteract harmful galvanic action. G-E Cathodic Protection Rectifiers, as part of a properly installed system, will do just that.

G-E Selenium Rectifier




### HOW IT WORKS

Engineers know corrosion occurs when one metal acts as a cathode, and another as an anode in an electrolyte, such as soil or water. The metal which acts as the anode slowly corrodes, pits, and eventually disintegrates.

The G-E Cathodic Protection Rectifier makes your pipeline the **cathode,** thereby eliminating galvanic actions, as shown in the sketch above.

### FAST INSTALLATION

The G-E Cathodic Protection Rectifier is shipped completely assembled. A bracket on the unit permits mounting directly on a pole or wall, and specially constructed foundations are not required. Connectors are designed for rapid installation.

### LOW MAINTENANCE

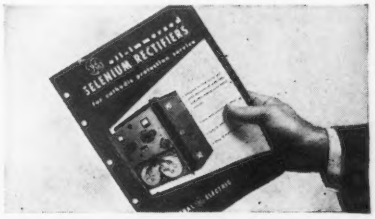
There are no moving parts to wear out in the G-E Cathodic Protection Rectifier. Hermetically sealed, oil-immersed selenium rectifier stacks are long-lived. Oil cannot oxidize or absorb moisture, and never has to be replaced. Access door facilitates meter reading, and inspection of the unit. Two spring clasps retain door, and a hasp is provided for padlocking.

### WITHSTANDS SEVERE WEATHER

General Electric's double-walled construction has been developed to withstand extreme variations in weather conditions, most common where cathodic protection is most essential.

### INFORMATION AVAILABLE

Because conditions differ in practically every installation, each cathodic protection system should be individually engineered to assure complete protection. For further information on the G-E Cathodic Protection Rectifier or on cathodic protection systems, write today for literature.




Authorized Distributor GENERAL ELECTRIC Cathodic Protection Rectifiers

462-8

THE Harco CORPORATION Cathodic Protection Division

OFFICES IN PRINCIPAL CITIES

16991 Broadway, Cleveland, Ohio

## NEW PRODUCTS

(Continued from Page 16)

of instruction in industrial spray finishing methods for users of deVilbiss equipment as follows: July 13, August 17, September 14, October 12, November 9 and December 7. Persons who wish to attend should write the company for reservations and more information.

•

**Unichrome 5300 Coatings,** which can be spray-applied to produce single coat dry films on cold vertical surfaces at room temperatures up to 20 mils in thickness are used to protect equipment against acids, alkalies, salts, oxidizing agents and other corrosives. Special formulations which are odorless, tasteless and non-toxic can be prepared. A short bake at 350 degrees F for special primer and coating are required. More information is available from United Chromium, Inc., 100 E. 42nd St., New York 17, N. Y.

•

**Banox,** a powdered rust inhibitor is being added to salt cubes in brine systems to reduce corrosion, according to Calgon, Inc., Hagan Bldg., Pittsburgh 30, Pa. Reduction of corrosion by salt brines by as much as 80 to 90 percent have been achieved in tests, making damage less than that ordinarily suffered from tap water. The material is used in proportion of one pound of Banox to 100 pounds of salt.

•

**Hagafilm,** a film-forming amine made by Hagan Corp., Hagan Bldg., Pittsburgh 30, Pa. is described in a new bulletin. Supplied as a solid or as an emulsion for mixing with hot condensate, the material vaporizes with the steam and is deposited as a very thin, non-wettable film on all metal surfaces where condensation occurs, reducing condensate corrosion. The material is safe to use where contact steam is used for cooking and sterilization. The company also says Haga film will clean out old iron oxide deposits and protect the system during standby.

•

**Beryllium** has had no bad effects detectable by x-ray survey among the workers of the Beryllium Corp. at Reading, Pa. A report issued by the Pennsylvania Health Department on the fifth chest x-ray survey of the company's employes showed no cases of disease attributed to beryllium. Employes have been free from beryllium poisoning despite unavoidable exposure to some dust of the metal in the air. Pure beryllium and certain compounds have been singled out as toxic agents, but commercial beryllium alloys are generally conceded to involve no danger.

•

**Plastic Applicators, Inc.,** 9110 Katy Road and Rubber Applicators, Inc., 9112 Katy Road, Houston have issued a joint bulletin describing their services. The firms apply plastic and rubber coatings to equipment for protection against corrosion and abrasion. Vinyl, furan, polyethylene and rubber base coatings are applied.

•

**Sealtite,** a flexible, liquid-tight electrical wiring conduit is a product of American Metal Hose Branch, American Brass Co., Waterbury 20, Conn. The conduit, made of zinc plated, interlocked steel strip, is coated with an extruded synthetic cover resistant to corrosive fumes, oil, dirt, chemicals and moisture.

•

**S-X Aluma-Flux,** a solder which manufacturers, Essex Wire Corp. says makes possible soldering of aluminum alloys without subsequent corrosion is distributed by Insulation and Wires, Inc., 3435 Chouteau Ave., St. Louis 3, Mo. The solder, effective on all aluminum alloys except a few with high silicon content, also can be used to join aluminum to other meals. The solder has been tested satisfactorily for soldering stainless steel, bare and galvanized carbon steel, cast iron and other ferrous metals, as well as copper, brass and nickel. Joining unlike metals also is accomplished. Tests of soldered joints of aluminum showed no corrosion after salt spray tests. Non-hydroscopic, the powdered flux can be stored indefinitely.

•

**Boltaron 6200** PVC structural shapes, bolts and nuts, pipe and fittings, sheets and blocks are described in a folder issued by H. N. Hartwell & Son, Inc., Park Square Bldg., Boston, Mass. A table shows resistance of the material to numerous corrosives.

•

**Alodine 1200** showed substantial superiority over chromic acid anodizing, conventional chromate treatment and Alodine 100 in a 500-hour salt spray test conducted on unpainted aluminum 24ST panels. American Chemical Paint Co., Ambler, Pa. describes the improved chemical as forming an amorphous mixed metallic oxide coating of low dielectric resistance on uncoated aluminum. It can be applied by dipping, power washing or with portable spray equipment. The three methods of application easily meet specification MIL-C-5541, the company says. It is recommended for coating wrought products that are not to be painted or are to be painted partially and for coating casting and forging alloys whether or not they are to be painted.

•

**Rite-Flo** Proportioners deliver a constant, predetermined quantity of liquid into a main line flow automatically adjusted to changed velocity and pressure, manufacturers say. Rite-Flo Engineering Co., 607 North Eighth St., Sheyboygan, Wis. suggests the device, built to fit standard pipe sizes up to six inches, is useful for adding inhibitors to flowing lines.

•

**Titanium** tubing with OD of only .0455-inch with a wall thickness of .00225-inch is being drawn by Superior Tube Co., Norristown, Pa. It is used for experimental work in electrical, electronic and chemical laboratories. The company also produces 54 other analyses of tubing, from ⅛-inch to 1½-inch outside diameter.

•

**Titeflex, Inc.,** 500 Freylinghuysen Ave., Newark 5, N. J. offers its Catalog No. 200 which describes helically-corrugated flexible metal hose, fittings and assemblies. Charts showing frictional losses versus flow rates are included. The methods used in manufacturing the hose are described and illustrated and numerous photographs show uses of the hose.

•

**Ed Conley Plastic Corp.,** 321 S. Quincy, Tulsa, Okla. manufactures glass fiber reinforced polyester and epoxy fittings for the oil and chemical industries. A 2-inch coupling has a bursting pressure of 2500 psi with a working pressure safety factor of 10 giving 250 psi.

•

**Varian Associates,** San Carlos, Cal. is producing Varian Model V-4300 High Resolution Nuclear Magnetic Resonance Spectrometers with which molecular structures are determined and components of a mixture identified. Principally applicable to compounds containing hydrogen and fluorine, the instrument can detect differences in the nmr structural spectra of isomers. Comparisons with oscilloscope traces of known compounds makes possible identification of the structures.

•

**Spring Packing Corp.,** 332 South Michigan Ave., Chicago 4, Ill. describes in Bulletin 125 a new series of cut-back asphaltic mastics with amorphous fillers. The coatings have a useful temperature range from —40 to plus 450 degrees F the company says and may be applied to damp surfaces.

•

**Beryllium** copper alloys No. 10, 25 and 165 are supplied in strip up to 8 inches wide and as thin as .0005-inch to tolerances as close as plus or minus .0001-inch by Industrial Div., American Silver Co., Inc., 36-07 Prince St., Flushing, N. Y. The material is used for corrosion resistant bushings, bearings, pump, valve and engine parts.

•

**Polyethylene** globe and Y valves with polyethylene-polyisobutylene diaphragm discs are being manufactured by the Vanton Pump Corp., Empire State Bldg., New York City. Recommended for working pressures up to 50 psi and temperatures to 150 degrees F the Vanilene valves are being made in sizes from ½-inch to 2-inch. Descriptive literature is available.

•

**V2B,** a new high-hardness, non-galling stainless alloy has been developed by Cooper Alloy Foundry Co., Hillside, N. J. for uses involving superior corrosion resistance. The alloy, a hardenable 18-8 stainless steel, contains copper, molybdenum, silicon and a very small amount of beryllium. It is readily machinable and may be hardened by a low temperature heat treatment which produces no distortion and light discoloration. Annealed, it may be welded using V2B rods. The alloy does not over-age at elevated temperatures and may be used in steam applications and at temperatures up to 1400 degrees F. The company says hardened V2B exceeds even Type 316 stainless in resistance to sulfuric, hydrochloric and phosphoric acids and their salts. It is superior to other hardenable grades in resistance to nitric acid but not quite equal to Types 304 or 316. It is suggested for use as valve discs, plug cocks, shaft sleeves, impellers, pump casings, wearing rings, poppets, conveyor links, rollers, gear blanks and other parts. It may be produced in both cast and wrought form.

•

**Soiltest, Inc.,** 4522 W. North Ave., Chicago 39, Ill. has issued a 72-page catalog describing and illustrating over 800 items of apparatus for engineering tests of soils, concrete and bituminous materials. A special section covers apparatus for chemical and agricultural tests of soils.

## PERSONALS

**Joseph C. Abeles** has been appointed vice-president and sales manager of Kawecki Chemical Co., Inc., Boyertown, Pa. Before joining Kawecki, for the past 17 years he was associated with Faesy & Besthoff, Inc., of New York City.

•

**Donald M. Anderson,** Attleboro Falls, Mass. has been named New England representative for Bart-Messing Corp., manufacturers of Sel-Rex selenium rectifiers and Sel-Rex Precious Metals, Inc., of Belleville, N. J.

•

**Robert J. Anderson,** consulting metallurgist, is located at 924 Mulberry Ave., San Antonio 1, Texas.

•

**Edward C. Badeau,** in charge of special publications section of the International Nickel Co., Inc., at New York and editor of Inco magazine, died suddenly May 24 from a heart attack. He had been with Inco since April, 1929. **John V. Moran, Jr.,** editor of the Inco employee publication "Pen and Inco" has been named to succeed Mr. Badeau. He joined Inco in 1946.

•

**Philip C. Blackburn,** specialist in petroleum training with the Petroleum Extension Service of the University of Texas, has been appointed Director of Engineering and Field Activities for the American Association of Oilwell Drilling Contractors.

•

**Arthur M. Brewer** has returned to Automotive Rubber Co., Detroit after 27 months' service with the air force at Lake Field Air Force Base near Phoenix, Ariz. Mr. Brewer, a World War II combat pilot, originally joined Arco at the end of the war.

•

**Howard S. Bunn** was elected Vice-President of Union Carbide and Carbon Corp., according to Morse G. Dial, president. Mr. Bunn has been President of Bakelite Co., a division of Union Carbide and Carbon Corp. He entered the Carbide organization in 1922 as a salesman. Another promotion went to John Conway who was made assistant sales manager for industrial chemicals of Carbide and Carbon Corp.

•

**Buckley M. Byers,** grandson of the founder of A. M. Byers Company, Pittsburgh, has been named general manager of wrought iron sales for the firm.

•

**Russel B. Caples** has been elected president and director of Anaconda Aluminum Company, New York City.

•

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(Continued on Page 21)


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Use TAPECOAT to combat corrosion above or below ground on gathering lines, transmission lines, meter stations, compressor stations, distribution lines, pipe joints, bolt-type couplings, fittings, large bends, large diameter pipe, insulated lines, tanks, and other surfaces subject to corrosion.

***Write for descriptive brochure and prices***

***The* TAPECOAT *Company***

*Originators of Coal Tar Tape Protection*

1521 Lyons Street, Evanston, Illinois

## NEW PRODUCTS

(Continued from Page 16)

of instruction in industrial spray finishing methods for users of deVilbiss equipment as follows: July 13, August 17, September 14, October 12, November 9 and December 7. Persons who wish to attend should write the company for reservations and more information.

•

**Unichrome 5300 Coatings,** which can be spray-applied to produce single coat dry films on cold vertical surfaces at room temperatures up to 20 mils in thickness are used to protect equipment against acids, alkalies, salts, oxidizing agents and other corrosives. Special formulations which are odorless, tasteless and non-toxic can be prepared. A short bake at 350 degrees F for special primer and coating are required. More information is available from United Chromium, Inc., 100 E. 42nd St., New York 17, N. Y.

•

**Banox,** a powdered rust inhibitor is being added to salt cubes in brine systems to reduce corrosion, according to Calgon, Inc., Hagan Bldg., Pittsburgh 30, Pa. Reduction of corrosion by salt brines by as much as 80 to 90 percent have been achieved in tests, making damage less than that ordinarily suffered from tap water. The material is used in proportion of one pound of Banox to 100 pounds of salt.

•

**Hagafilm,** a film-forming amine made by Hagan Corp., Hagan Bldg., Pittsburgh 30, Pa. is described in a new bulletin. Supplied as a solid or as an emulsion for mixing with hot condensate, the material vaporizes with the steam and is deposited as a very thin, non-wettable film on all metal surfaces where condensation occurs, reducing condensate corrosion. The material is safe to use where contact steam is used for cooking and sterilization. The company also says Haga film will clean out old iron oxide deposits and protect the system during standby.

•

**Beryllium** has had no bad effects detectable by x-ray survey among the workers of the Beryllium Corp. at Reading, Pa. A report issued by the Pennsylvania Health Department on the fifth chest x-ray survey of the company's employes showed no cases of disease attributed to beryllium. Employes have been free from beryllium poisoning despite unavoidable exposure to some dust of the metal in the air. Pure beryllium and certain compounds have been singled out as toxic agents, but commercial beryllium alloys are generally conceded to involve no danger.

•

**Plastic Applicators, Inc.,** 9110 Katy Road and Rubber Applicators, Inc., 9112 Katy Road, Houston have issued a joint bulletin describing their services. The firms apply plastic and rubber coatings to equipment for protection against corrosion and abrasion. Vinyl, furan, polyethylene and rubber base coatings are applied.

•

**Sealtite,** a flexible, liquid-tight electrical wiring conduit is a product of American Metal Hose Branch, American Brass Co., Waterbury 20, Conn. The conduit, made of zinc plated, interlocked steel strip, is coated with an extruded synthetic cover resistant to corrosive fumes, oil, dirt, chemicals and moisture.

•

**S-X Aluma-Flux,** a solder which manufacturers, Essex Wire Corp. says makes possible soldering of aluminum alloys without subsequent corrosion is distributed by Insulation and Wires, Inc., 3435 Chouteau Ave., St. Louis 3, Mo. The solder, effective on all aluminum alloys except a few with high silicon content, also can be used to join aluminum to other meals. The solder has been tested satisfactorily for soldering stainless steel, bare and galvanized carbon steel, cast iron and other ferrous metals, as well as copper, brass and nickel. Joining unlike metals also is accomplished. Tests of soldered joints of aluminum showed no corrosion after salt spray tests. Non-hydroscopic, the powdered flux can be stored indefinitely.

•

**Boltaron 6200** PVC structural shapes, bolts and nuts, pipe and fittings, sheets and blocks are described in a folder issued by H. N. Hartwell & Son, Inc., Park Square Bldg., Boston, Mass. A table shows resistance of the material to numerous corrosives.

•

**Alodine 1200** showed substantial superiority over chromic acid anodizing, conventional chromate treatment and Alodine 100 in a 500-hour salt spray test conducted on unpainted aluminum 24ST panels. American Chemical Paint Co., Ambler, Pa. describes the improved chemical as forming an amorphous mixed metallic oxide coating of low dielectric resistance on uncoated aluminum. It can be applied by dipping, power washing or with portable spray equipment. The three methods of application easily meet specification MIL-C-5541, the company says. It is recommended for coating wrought products that are not to be painted or are to be painted partially and for coating casting and forging alloys whether or not they are to be painted.

•

**Rite-Flo** Proportioners deliver a constant, predetermined quantity of liquid into a main line flow automatically adjusted to changed velocity and pressure, manufacturers say. Rite-Flo Engineering Co., 607 North Eighth St., Sheyboygan, Wis. suggests the device, built to fit standard pipe sizes up to six inches, is useful for adding inhibitors to flowing lines.

•

**Titanium** tubing with OD of only .0455-inch with a wall thickness of .00225-inch is being drawn by Superior Tube Co., Norristown, Pa. It is used for experimental work in electrical, electronic and chemical laboratories. The company also produces 54 other analyses of tubing, from ⅛-inch to 1½-inch outside diameter.

•

**Titeflex, Inc.,** 500 Freylinghuysen Ave., Newark 5, N. J. offers its Catalog No. 200 which describes helically-corrugated flexible metal hose, fittings and assemblies. Charts showing frictional losses versus flow rates are included. The methods used in manufacturing the hose are described and illustrated and numerous photographs show uses of the hose.

•

**Ed Conley Plastic Corp.,** 321 S. Quincy, Tulsa, Okla. manufactures glass fiber reinforced polyester and epoxy fittings for the oil and chemical industries. A 2-inch coupling has a bursting pressure of 2500 psi with a working pressure safety factor of 10 giving 250 psi.

•

**Varian Associates,** San Carlos, Cal. is producing Varian Model V-4300 High Resolution Nuclear Magnetic Resonance Spectrometers with which molecular structures are determined and components of a mixture identified. Principally applicable to compounds containing hydrogen and fluorine, the instrument can detect differences in the nmr structural spectra of isomers. Comparisons with oscilloscope traces of known compounds makes possible identification of the structures.

•

**Spring Packing Corp.,** 332 South Michigan Ave., Chicago 4, Ill. describes in Bulletin 125 a new series of cut-back asphaltic mastics with amorphous fillers. The coatings have a useful temperature range from —40 to plus 450 degrees F the company says and may be applied to damp surfaces.

•

**Beryllium** copper alloys No. 10, 25 and 165 are supplied in strip up to 8 inches wide and as thin as .0005-inch to tolerances as close as plus or minus .0001-inch by Industrial Div., American Silver Co., Inc., 36-07 Prince St., Flushing, N. Y. The material is used for corrosion resistant bushings, bearings, pump, valve and engine parts.

•

**Polyethylene** globe and Y valves with polyethylene-polyisobutylene diaphragm discs are being manufactured by the Vanton Pump Corp., Empire State Bldg., New York City. Recommended for working pressures up to 50 psi and temperatures to 150 degrees F the Vanilene valves are being made in sizes from ½-inch to 2-inch. Descriptive literature is available.

•

**V2B,** a new high-hardness, non-galling stainless alloy has been developed by Cooper Alloy Foundry Co., Hillside, N. J. for uses involving superior corrosion resistance. The alloy, a hardenable 18-8 stainless steel, contains copper, molybdenum, silicon and a very small amount of beryllium. It is readily machinable and may be hardened by a low temperature heat treatment which produces no distortion and light discoloration. Annealed, it may be welded using V2B rods. The alloy does not over-age at elevated temperatures and may be used in steam applications and at temperatures up to 1400 degrees F. The company says hardened V2B exceeds even Type 316 stainless in resistance to sulfuric, hydrochloric and phosphoric acids and their salts. It is superior to other hardenable grades in resistance to nitric acid but not quite equal to Types 304 or 316. It is suggested for use as valve discs, plug cocks, shaft sleeves, impellers, pump casings, wearing rings, poppets, conveyor links, rollers, gear blanks and other parts. It may be produced in both cast and wrought form.

•

**Soiltest, Inc.,** 4522 W. North Ave., Chicago 39, Ill. has issued a 72-page catalog describing and illustrating over 800 items of apparatus for engineering tests of soils, concrete and bituminous materials. A special section covers apparatus for chemical and agricultural tests of soils.

## PERSONALS

**Joseph C. Abeles** has been appointed vice-president and sales manager of Kawecki Chemical Co., Inc., Boyertown, Pa. Before joining Kawecki, for the past 17 years he was associated with Faesy & Besthoff, Inc., of New York City.

•

**Donald M. Anderson,** Attleboro Falls, Mass. has been named New England representative for Bart-Messing Corp., manufacturers of Sel-Rex selenium rectifiers and Sel-Rex Precious Metals, Inc., of Belleville, N. J.

•

**Robert J. Anderson,** consulting metallurgist, is located at 924 Mulberry Ave., San Antonio 1, Texas.

•

**Edward C. Badeau,** in charge of special publications section of the International Nickel Co., Inc., at New York and editor of Inco magazine, died suddenly May 24 from a heart attack. He had been with Inco since April, 1929. **John V. Moran, Jr.,** editor of the Inco employee publication "Pen and Inco" has been named to succeed Mr. Badeau. He joined Inco in 1946.

•

**Philip C. Blackburn,** specialist in petroleum training with the Petroleum Extension Service of the University of Texas, has been appointed Director of Engineering and Field Activities for the American Association of Oilwell Drilling Contractors.

•

**Arthur M. Brewer** has returned to Automotive Rubber Co., Detroit after 27 months' service with the air force at Lake Field Air Force Base near Phoenix, Ariz. Mr. Brewer, a World War II combat pilot, originally joined Arco at the end of the war.

•

**Howard S. Bunn** was elected Vice-President of Union Carbide and Carbon Corp., according to Morse G. Dial, president. Mr. Bunn has been President of Bakelite Co., a division of Union Carbide and Carbon Corp. He entered the Carbide organization in 1922 as a salesman. Another promotion went to John Conway who was made assistant sales manager for industrial chemicals of Carbide and Carbon Corp.

•

**Buckley M. Byers,** grandson of the founder of A. M. Byers Company, Pittsburgh, has been named general manager of wrought iron sales for the firm.

•

**Russel B. Caples** has been elected president and director of Anaconda Aluminum Company, New York City.

•

**Dr. William W. Coblentz,** retired National Bureau of Standards physicist has received the second Annual Award of the Society for Applied Spectroscopy in recognition of his pioneering work in the field of infrared spectroscopy.

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## PERSONALS

(Continued from Page 19)

**Carl T. Dowling,** South Amboy, N. J. has been named New Jersey representative of Bart-Messing Corp., Belleville, N. J.

•

**C. L. Garner** has been named sales manager of Tube-Kote, Inc., Houston, applicators and manufacturers of corrosion-resistant linings for tubular equipment. The announcement was made by **L. E. Heinen**, president of Tube-Kote, Inc. Mr. Garner is a member of NACE and of the Houston Engineers Club. His new post includes supervision of sales of Tube-Kote services dealing primarily with oil and chemical firms.

•

**Sam E. Gewin** has been appointed district manager of the St. Louis office of The Bristol Co., Waterbury, Conn., manufacturers of recording and controlling instruments.

•

**L. E. Grubb** has been appointed General superintendent of the Huntington, W. Va., Works of the International Nickel Company, Inc., according to an announcement by **Dr. Paul D. Merica,** president of the company. At the same time, **P. H. Flynn** was named general superintendent of Inco's Bayonne, N. J. Works to succeed Mr. Grubb. Mr. Flynn was formerly assistant superintendent to Mr. Grubb at the Bayonne Works.

•

**Carter F. Horton,** a University of Texas graduate and **William R. Penland,** a University of Texas and Rice Institute graduate have joined the corrosion engineering staff of the Hinchman Corp., Detroit. Mr. Penland has had wide experience in the engineering and testing of corrosion mitigation systems, especially on pipe line projects. **John A. Michelson,** an Ohio University graduate, an experienced metallurgical engineer, has joined the corrosion engineering staff also.

•

**John L. Keating** has been named Production manager of The Cooper Alloy Foundry Co., Hillside, N. J.

•

**H. L. Klein** has been named treasurer and assistant secretary of Ebasco Services, Inc., New York.

•

**Erhardt C. Koerper** is now works manager of Ampco Metal, Inc., Milwaukee, Wis., according to a company announcement. He will direct the company's entire production activity. Ampco produces special copper-base alloys, principally "Ampco Metal," a series of high aluminum, high iron aluminum bronzes.

•

**Carl A. Odening,** superintendent of the Columbia, Tenn. plant of National Carbon Company, a division of Union Carbide and Carbon Corp. has been awarded the Alfred P. Sloan fellowship under the executive development program at Massachusetts Institute of Technology.

•

**James W. McLaughlin,** vice president of Union Carbide and Carbon Corp. died suddenly May 15 at his home in New Rochelle.

•

**Anthony A. Miano** has been appointed Standards Supervisor in the Stainless Engineering & Machine Works Div. He has had 14 years experience in the field.

•

**Herbert E. Miles** has been appointed director of the Glidden Company's Nubian Industrial Div., Midwest Region, it was announced by **A. D. Duncan,** vice president and general manager of Glidden's Paint and Varnish Div. Mr. Miles suc-

(Continued on Page 22)

HERE'S NEW OPPORTUNITY FOR A CORROSION RESEARCH MAN

Have you at least 5 years of industrial or institutional experience in the development and formulation of rust preventives, protective coatings, petro chemicals, wax and oil type hydrocarbons, corrosion inhibitors, etc.?

Also the successful applicant will have a creative approach to research plus the ability to stimulate co-workers.

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- Advertisements to other specifications will be charged for at standard rates.

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•

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•

**Corrosion Engineer**—For laboratory work on corrosion problems of research and development nature. Infrequent travel. Chemical, electrical or metallurgical background preferred. $4-$6000 per annum, N. Central Jersey location. Reply CORROSION, Box 53-11.

•

**Corrosion Engineer**—Chemical or metallurgical background. Sell metallizing and hardfacing equipment in New England area for concern also equipped to do work. Right man will complete nucleus for fast growing plant. New England Hard Facing Co., 678 Brookline Ave., Brookline 46, Mass.

•

**Corrosion Engineer**—Major oil company has position for chemical engineering graduate with 2-3 years oil production or petroleum engineering experience for training as corrosion engineer. Age and salary open. Will headquarter in Houston but must be able to travel. Reply giving full particulars. CORROSION, Box 53-12.

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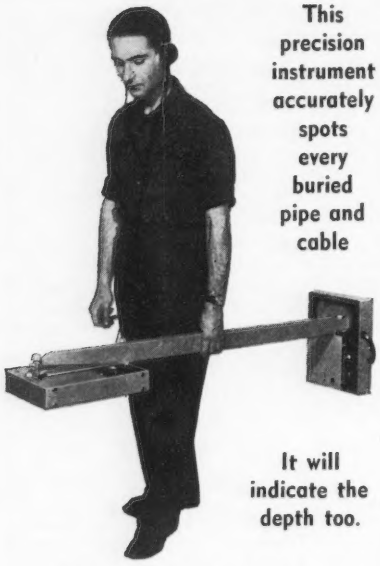

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## PERSONALS

(Continued from Page 21)

ceeds **Chester C. Johnson,** who will retire after directing the division for the past 24 years.

•

**George C. Miller** has been appointed president of Bakelite Company, a division of Union Carbide and Carbon Corp. He succeeds **H. S. Bunn,** vice-president of Union Carbide, who now succeeds the late J. W. McLaughlin as chairman of Bakelite.

•

**Don G. Mitchell** was elected chairman of the board and **H. Ward Zimmer** was elected president of Sylvania Electric Products, Inc., it was announced by the Board of Directors of the company.

•

**Philip H. Moore,** Albany House, Esplanade, Durban, Natal has been appointed sales and service representative for Southern Africa by T. W. Williamson, Inc. Mr. Moore is a graduate of Birmingham University and formerly was with Manchester Oil Refinery, Ltd.

•

**Carl H. Pottenger** has been appointed assistant vice-president and Division Sales Manager of Chemical Division of Koppers Company, Inc.

•

**Tom Stott** has been appointed vice-president of the H. M. Harper Co., Morton Grove, Ill., according to an announcement by **H. M. Harper,** president of the firm. He will continue to serve in his capacity of General Sales Manager.

•

**Dr. J. Bartlett Sutton** has been named sales manager of specialty products in the Pigments Department headquarters of E. I. DuPont de Nemours & Co., Inc., at Wilmington, Del.

•

**Charles B. Weiler** has been appointed vice-president-in-charge of industrial insulation with Earl Paint Corp., Utica, N. Y., manufacturers of industrial mastics. He has been associated with the firm in a sales engineering capacity since 1948.

•

**W. F. Winkler** has been appointed equipment sales manager of Midwestern Engine & Equipment Co., Inc., according to an announcement by Armon H. Bost, vice-president and general manager of the firm. He came to Midwestern from the Oliver Corp. when the equipment company acquired the Oliver Tractor line for the Southwest area.

## *Arc Welding Reprint*

"The Inert-Gas-Shielded Metal-Arc Welding Process," a lecture series presented at the Annual Meeting of the American Welding Society, reprinted from The Welding Journal for April and May, 1953 is available as a reprint at $1 a copy from AWS at 33 West 39th St., New York 18, N. Y. The illustrated lectures describe the theory and technique of the inert arc process and give practical information of techniques.

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•

**It's easy to apply. Stir and brush on like ordinary paint. Only one coat required.**

*Bulletin 150 describes some rigid tests made of Rustbond Primer by some of the country's largest chemical plants.*

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*Specialists in Corrosion Resisting Synthetic Materials*

CORROSION CONTROL — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

# Corrosion Abstracts

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## 1. GENERAL

### 1.1 Miscellaneous

1.1, 1.3, 1.6

**Report of the Chemistry Research Board with the Report of the Director of the Chemical Research Laboratory for the Year 1950.** Dept. of Scientific and Industrial Research, His Majesty's Stationery Office (London), 1951, 104 pp.

The main lines of research at present in progress include corrosion of metals; high polymers and plastics; new techniques; less common elements including radioactive metals; and purification of organic compounds, particularly those derived from tar and those containing heavy carbon. The laboratory maintains close contact with academic chemistry, the various industries concerned, and other government organizations with common interests.—BLR.

1.1, 1.6

**Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources. Vol. II. Mineral Resources** 303 pages. 1951. Department of Economics Affairs, United Nations, New York.

Series of papers and accompanying discussion, appearing under the following broad headings: Mineral Supplies and Their Measurement; The Outlook for Future Discovery, Increasing Mineral Resources by Discovery; Conservation in Mining and Milling; Conservation in Manufacture; Conservation by

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ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italian. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

Corrosion Control; Conservation by Substitution; and Inorganic Fertilizers in Conservation. Selected papers are separately abstracted.—BTR.

## 1.2 Importance

1.2.2, 4.5.3, 6.2.1

**Cost and Benefits of Conservation of Cast Iron and Steel Pipelines by Control of Corrosion.** J. E. CARRIERE AND C. A. LOBRY DE BRUYN. "Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources. Vol. II. Mineral Resources," 234-237, 240-244 (1951).

Surveys soil conditions in the Netherlands. Data are presented on total length and value of existing water and gas mains in the Netherlands. The Dutch Corrosion Committee's specifications for pipe castings are described. Regarding testing of soils for corrosiveness, a chemical and physical examination procedure is outlined. Economic advantages of a high-grade protective coating over a cheap coal-tar dip are calculated.—BTR.

1.2.5

**Corrosion Hazards.** J. B. DELAUNE. *Proc. Amer. Petroleum Inst.*, **31M**, No. 3, 134 (1951).

A brief note on the part which should be played by the corrosion engineer in a safety programme in the oil industry.—MA.

## 1.4 Bibliographies

1.4, 1.6

**Punched Cards—Their Applications to Science and Industry.** Edited by Robert S. Casey and James W. Perry. 506 pages, 6 x 9 inches, cloth. 1951. Reinhold Publishing Corp., 330 West 42nd St., New York, N. Y. Per Copy. $10.00.

The editors assume readers are unacquainted with punch cards and their uses and proceed from the simple to the complex. Topical and author indices are included. Illustrated with diagrams and charts, use is made easy by the inclusion of specific case histories giving details of working files using punched cards. Part III is devoted to general and fundamental considerations including suggestions on coding, mathematical analysis of coding systems, and expositions of various problems related to indexing, classification systems, transcription problems and other factors. Part IV is devoted to an estimation of the future possibilities of punched cards. A bibliography of uses and subject and author indices are included.

# 2. TESTING

## 2.3 Laboratory Methods and Tests

2.3.9, 3.2.3, 3.8.4

**Adsorption of Carbon Dioxide on a Nickel Single Crystal Using a Radioactive Tracer.** A. D. CROWELL AND H. E. FARNSWORTH. *J. Chem. Physics*, **19**, No. 9, 1206, 1207 (1951).

A letter. Preliminary measurements of carbon dioxide chemisorption on small polycrystalline metal surfaces, using $C^{14}$ as a tracer, indicate irreversible adsorption on copper and nickel, reversible adsorption on silver, and adsorption in nickel on exposure at ~ 400°C. Determination made on the polished (111) face of a nickel single crystal showed measurable amounts of carbon dioxide but the results were not reproducible, apparently owing to changing surface conditions arising from exposure to air during counting. The tracer technique is considered suitable for gas chemisorption studies on single crystals, though a method in which the surface is not exposed to air between measurements is desirable. The technique used is described and the apparatus illustrated.—MA.

## 2.4 Instrumentation

2.4.2, 4.3.2, 5.3.1, 5.4.1

**Coatings Tester.** *Chem. Week*, **68**, No. 6, 23-24 (1951) Feb.

The Bureau of Standards' new lab has automatic control of all functions and of the temperature and purity of water within narrow limits, for accelerated durability tests of exterior protective coatings. Enclosed in one hood are six machines which use the enclosed carbon arc as a source of light. An aluminum drum holding 60 exposure panels is rotated around each arc once a minute. Air is circulated at a low velocity until the panels reach a predetermined maximum temperature. Then a heat-sensitive element mounted in one of the panels turns on the high speed blower, speeding up the air flow and cooling the panels. Deionized water, controlled by a cycle clock, can be sprayed on the test panels for any portion of their exposure period. The heart of each machine is a time relay which turns off all functions if the arc should cease to operate for more than 30 seconds. To supplement the machines and permit a correlation with actual weathering, the Bureau has built a set of exposure decks on the roof of the laboratory that will hold 3,000 test panels. —INCO.

2.4.3, 1.3

**Development of Nondestructive Materials Testing. Parts I-II.** (In German.) RUDOLF BERTHOLD. *Chem. Ing. Tech.*, **23**, 33-38, 65-68 (1951) Jan. 28, Feb. 14.

Part I describes methods and equipment for the above developed and perfected in recent years, including irradiation and magnetic methods. Domestic and foreign procedures and equipment are compared. Part II deals with electrical, acoustic, thermal, and chemical processes. Tables, graphs, and diagrams are presented. 109 references.—BLR.

2.4.3, 2.3.9

**New Methods for Non-Destructive Inspection.** THOMAS A. DICKINSON. *Welding Engineer*, **36**, 56-58 (1951) Oct.

Discusses both old and new test methods in the above. New methods such as radioactive isotopes, painting the flaws, and xerographic radiography are explained and described.—BLR.

# 3. CHARACTERISTIC CORROSION PHENOMENA

## 3.2 Forms

3.2.2

**An Experimental Investigation of the Diffusion of Electrolytic Hydrogen Through Metals.** H. R. HEATH. *Brit. J. Applied Phys.*, **3**, 13-18 (1952) Jan.

An investigation was made on iron, nickel, cobalt, copper, zinc, silver, palladium, platinum, and lead. A theory explaining the general character of the results is given. 12 references.—BLR.

3.2.2, 1.3, 6.2.3

**Hydrogen Embrittlement of Steel: Review of the Literature.** R. W. BUZZARD AND H. E. CLEAVES. U. S. Natl. Bureau Standards Circ. 511, Sept. 24, 1951, 29 pp. Obtainable from Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C. U.S.A. 20 cents.

Based on a select bibliography of nearly 1200 references, up to 1949. Conclusion is that the data in the literature fail to establish quantitative proof that hydrogen is the sole cause of all the defects which have been attributed to it, but it is well established that when procedures are adopted for maintaining the hydrogen content at a minimum, certain defects can be eliminated.—BNF.

3.2.2, 6.2.3

**Effect of Hydrogen on the Deformation and Fracture of Iron and Steel in Simple Tension.** P. BASTIEN AND P. AZOU. Paper before 1st World Metallurgical Congr., Detroit, Oct. 1951. Proc. 1st World Metallurgical Congress, ASM, 535-552 (1951).

Hydrogen introduced into iron and mild steel has little effect on flow properties, but it is found to lower both true fracture stress and strain. It increases the transition temperature. The embrittlement disappears below 110°C but reappears on reheating to room temperature. The embrittlement is strain rate sensitive disappearing at very high rates being low at very low rates, and having its maximum effect at medium strain rates. Tables, graphs and 16 references are included.—INCO.

3.2.3, 3.8.2

**The Flow of Ions and Electrons Through Thin Aluminum Oxide Films.** A. CHARLESBY, Atomic Energy Research Establishment, Harwell, Berks (England). 1951, 78 p.

This report studies the growth of oxide layers on aluminum and some of the electrical phenomena associated with the growth. Ultraviolet radiation is known to produce changes in oxide thickness on other metals, e.g., tantalum but in the case of aluminum the effect is very small. However, ultraviolet radiation does produce electrical changes in the film, and it is these changes which have been studied. To allow the greatest degree of control over the conditions of growth, electrolytic anodization is used. The main factors involved are the current through the film, the potential difference V applied, the film thickness $\delta$, time, and temperature. The mean field $F(= V/\delta)$ is found to be an important factor determining film growth. The capacity C of the condenser formed by the insulating oxide layer between the metal and electrolyte is also considered, since it is a measure of film thickness. The total current i passing through the film is found to consist of the ion current i+, which consists of $Al^{+3}$ ions and builds up the film, and the electron current i—, which has no appreciable permanent effect and appears to be associated with impurities or structural defects. (Author.)—NSA.

3.2.3, 3.8.4

**The Scaling Behavior of Metals.** JAMES T. WABER. Los Alamos Scientific

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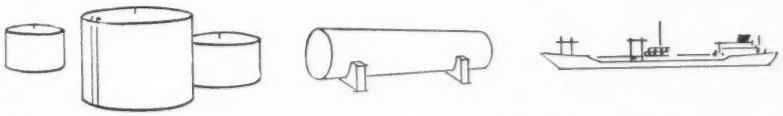

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103a

Lab. (No date) 24 p. (AECU-1854; LADC-1080).

An extensive amount of practical information concerning the scaling of metals has been accumulated during the past fifty years. A few of the reasonable generalizations are given which have been derived from this information, together with facts which appear to be anomalous. In metal-scaling research, four definite scale-growth laws have been accepted. In the order of their decreasing frequency they are the parabolic, the linear, the logarithmitic, and the cubic laws. These laws are discussed independently. In conclusion, the idea that the ratio of the oxide-to-metal volume indicates whether scaling should take place by one growth law or another has proved to be only partially successful. Temperature and time have profound effects upon scaling but are not yet clearly understood.—NSA.

3.2.3, 5.4.2, 5.9.4

**Oxide Films; Their Effect on Tin Plate.** J. G. DONELSON. *National Lithographer*, **58**, 36-37, 83-86 (1951) Aug.

Causes of oxide films and methods of retarding the film by treatment. Effects of oxide coatings on tin plate and methods of producing improved protective films that will be compatible with the best lacquers.—MR.

3.2.3, 5.9.4, 3.4.6

**The Artificial Thickening of the Oxide Film on Aluminum by Chemical Means: New Method of Producing Protective Coatings on Light Metals.** (In Hungarian.) ANDRAS DOMONY. *Aluminum* (Budapest), **3**, No. 4, 73-77 (1951).

Theoretical and experimental data are given. The results of corrosion tests showed that specimens treated with the M.B.V. process (which is briefly described) suffered the least weight loss in a number of highly corrosive substances. 9 references.—MA.

3.2.3, 6.3.6, 4.3.3

**Corrosion of Copper Powder: Recent Russian Research.** *Chem. Age*, **65**, 171-473 (1951) Oct. 6.

Reviews results published in Russia between 1935 and 1950. Presence of ammonium salts has been found to be a particularly active factor in copper corrosion, whether metal is produced or not. Details of test procedure is given. Presence of moisture is regarded as indispensable factor in atmospheric corrosion. Film theory of Kistyakovski, mechanism of atmospheric corrosion, formation of hydrophobic films of metal surfaces and results from wettability tests of samples previously exposed to corrosion and then coated with soap are discussed.—INCO.

## 3.3 Biological Effects

3.3.2, 4.6.11, 1.6

**Marine Fouling and Its Prevention.** United States Naval Institute, Annapolis, Maryland. 400 pp. 10½ x 8, illustrated. Per Copy, $10.00. 1952.

Cost of barnacles and other fouling organisms costs the U. S. Shipping Industry alone more than $100,000,000 yearly. The book details research done by the Bureau of Ships, Navy Department and Woods Hole Oceanographic Institution. The book is recommended to commercial shipowners and operators, to ship yards, managers of docks and piers, to yacht owners, and to manufacturers of marine construction materials and paints and to any shore industries utilizing sea water for industrial purposes. In one New England power station utilizing sea water, 266 tons of marine shells have been removed from the salt water tunnel within a single year. The book relates the early attempts at developing an anti-fouling protection for ship bottoms. In 1625, Britain issued patents for an antifouling ship-bottom paint, but it was not until over 200 years later that the first fairly successful preparation was formulated—copper sulfate in yellow soap. Cost of docking, scraping and bottom-painting the superliner, United States, is estimated at $75,000. More than a decade ago, cost of docking, scraping and painting the bottom of an 18,000 ton ship was $4400. The price is higher now. The book is written in 3 parts. 1. "Problems of Fouling," takes up the Effects of Fouling and Ship Resistance. 2. "Biology of Fouling." 3. "Prevention of Fouling" takes up the physical chemistry of compounds of copper and mercury and their interaction with sea water, mechanisms of release of toxics from paints, characteristics of anti-fouling coatings, the design of anti-fouling paints, fouling of metallic surfaces, interaction of anti-fouling paints and steel and other like topics.

3.3.2, 5.4.8, 4.6.11

**Problems of Corrosion and Marine Fouling.** M. G. DECHAUX. *Peintures Pigments vernis*, **27**, No. 5, 282-286 (1951).

A review of methods of testing and evaluating underwater paints. Electrochemical phenomena are invoked to explain anomalous behavior; the practice of quartering the underwater hull with different paints is condemned. To evaluate an anti-fouling paint, statistical examination of results from immersed test panels, in widely scattered locations, is first made, then the best paints are applied separately on sea-going vessels; final judgment is made on the basis of examination of the entire hull; thus: a) the proportion of surface occupied by definite fouling organisms, e.g., brown algae, green algae, zalaindae and serpulae, to the exclusion of other types; b) distribution of the named types; c) proportion of surface denuded of anti-fouling paint; d) proportion of bare surface.—RPI.

## 3.4 Chemical Effects

3.4.6, 3.5.3, 6.5

**Oxidation, Corrosion, and Wear in Metals and Alloys.** J. DENAX. *Tecnica e industria* (Buenos Aires), **29**, 1367-1370 (1951).

A very general note on some forms of oxidation, corrosion, and wear, including tables showing the effects of corrosion on aluminum and on magnesium, copper, iron, nickel, and chromium alloys.—MA.

## 3.5 Physical and Mechanical Effects

3.5.8, 3.7.3, 8.9.3

**Report on Investigations into the Stress-Corrosion Cracking in Welded (Steel) Gas Mains.** British Welding Research Association. Inst. Gas Engineers Copyright Pubn. No. 398, Nov., 1951, 31 pp.

The investigations were inconclusive as regards the nature of the corrosive agent (although it was shown that ammonia must be present for cracking to occur), but the results justify the recommendation of stress relieving. Some of the specimens tested were sprayed with aluminum, nickel, Monel, and stainless steel, others were coated with zinc paint.—BNF.

3.5.8, 6.4.1, 3.8.4

**A Mechanism of Stress-Corrosion in Aluminum-Magnesium Alloys.** C. EDELEANU. *J. Inst. Metals*, **80**, No. 4, 187-191 (1951).

The attack on aluminum and aluminum-rich alloys, immersed in neutral chloride solution, tends to become restricted to a limited area owing to the autocatalytic nature of the anodic reaction. On homogeneous alloys, corrosion causes scattered pits which can increase either in depth or in area; but in the case of alloys possessing a path of easy corrosion, the attack takes the form of trenching and is confined to the tips of the cracks so formed. This latter type of corrosion leads to great mechanical weakening, even though the actual rate of attack unit area may not be very different in the two instances. The nature of the path of easy corrosion is unknown, but there is evidence that it is sub-microscopic in width. No indication has been found that, in the case of aluminum-magnesium alloys, it consists of the equilibrium second phase, $\beta$. From experiments carried out on aluminum-7% magnesium alloy, it is concluded that stress exerts no influence during the first stages of the process (the greater part of the life), but that corrosion plays a vital role during the final rapid cracking. (Author.)—MA.

3.5.9, 6.2.5

**Cast Heat Resistant Alloys of the 21% Chromium-9% Nickel Type.** HOWARD S. AVERY, CHARLES R. WILKS, AND JOHN A. FELLOWS. American Society for Metals, Preprint 15, 1951, 24 pages.

Characteristics of above alloys intended for 1200°-1600°F service are reported in detail with data covering room-temperature mechanical properties as-cast and after aging at 1400° F; creep and creep-rupture properties from 1200° to 1600° F; magnetic permeability after various thermal treatments; behavior in hindered thermal contractions; resistance to oxidation at elevated temperatures; hot-hardness variation with temperature; influences of thermal history on structure; and miscellaneous physical properties such as density, melting point, modulus of elasticity, and coefficients of thermal expansion. Comparisons with cast 26% chromium + 12% nickel ("HH" type) alloys show superior aged ductility with equivalent creep strength and satisfactory oxidation resistance up to 1600°F. —BLR.

## 3.6 Electrochemical Effects

3.6.2, 6.3.6

**Black Spots on Brass.** (In French and German.) PAUL DUCOMMUN. *Pro-Metal*, **4**, 925-927 (1951) Dec.

Proposes an explanation of above phenomenon. Because of differential aeration, corrosion results from the formation of small galvanic concentration cells in wet spots between brass plates. Describes experiments verifying the theoretical explanation.—BTR.

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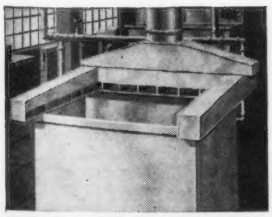

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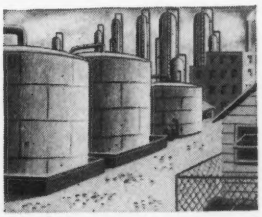

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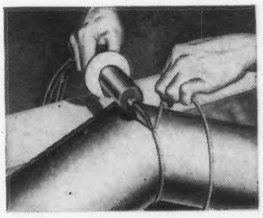

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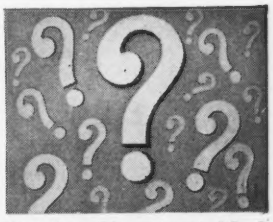

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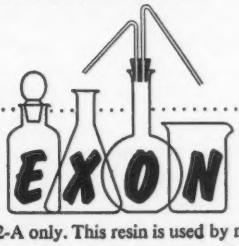


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3.6.5, 6.2.2

**The Rate of Solution and Solution Potentials of Iron.** (In Russian.) Ia V Durdin and M. A. Oranskaia. *J. Gen. Chem. (U.S.S.R.), (Zhurnal Obshchei Khimii)*, **21**, No. 83, 604-614 (1951) April.

Rate of solution and the solution potentials of Armco iron and commercial roofing iron in 10 normal hydrochloric acid and sulfuric acid were determined. Data are discussed, tabulated, and charted. 11 references.—BLR.

3.6.5, 6.3.11

**Potential-pH Diagram of Silver. Electrochemical Behavior and Corrosion of Silver.** (In French.) P. Delahay, M. Pourbaix, and P. Van Rysselberghe. "International Committee on Electrochemical Thermodynamics and Kinetics; Proceedings of the 2nd Meeting" (Libreria Editrice Politecnica Cesare Taburini, Milan, Italy), **1951**, p. 29-33..

The electrochemical equilibrium diagram of the silver-water system was established as a function of the pH and the potential. This diagram was applied to a study of the electrochemical behavior of silver and its compounds, and to a study of the corrosion of silver. Diagrams.—MR.

3.6.5, 6.3.19

**Potential-pH Diagram of Zinc. Electrochemical Behavior and Corrosion of Zinc.** (In French.) P. Delahay, M. Pourbaix, and P. Van Rysselberghe. "International Committee on Electrochemical Thermodynamics and Kinetics; Proceedings of the 2nd Meeting" (Libreria Editrice Politecnica Cesare Taburini, Milan, Italy), **1951**, 34-41 p.

The Electrochemical equilibrium diagrams of the zinc-water and zinc-carbon dioxide-water systems are established as a function of the pH and potential. They are applied to study of the electrochemical behavior of zinc and its compounds, and to the study of corrosion of zinc. Includes diagrams.—BTR.

3.6.5, 6.3.8

**Potential-pH Diagram of Lead. Electrochemical Behavior and Corrosion of Lead. Lead Batteries.** (In French.) P. Delahay, M. Pourbaix, and P. Van Rysselberghe. "International Committee on Electrochemical Thermodynamics and Kinetics; Proceedings of the 2nd Meeting" (Libreria Editrice Politecnica Cesare Taburini Milan, Italy), **1951**, p. 15-28.

The electrochemical equilibrium diagrams of the lead-water system, and of the lead-carbon dioxide-water and lead-sulfate-water systems are established as a function of pH and potential. These diagrams are applied to a study of the electrochemical behavior of lead and its compounds; to the study of corrosion, passivation, and passivity of lead; and to the study of lead cells. Diagrams and graphs. 11 references.—MR.

3.6.8, 1.3

**Overpotential.** J. O'M. Bockris. *J. Electrochem. Soc.*, **98**, No. 11. 153c-157c (1951).

The significance of the concept of over-potential to the whole of electrode process chemistry is emphasized. Past work on the subject is reviewed, and brief suggestions are made for future work. 28 references.—MA.

3.6.8, 1.6

**Overpotential.** J. O'M. Bockris. "Electrical Phenomena at Interfaces." Macmillan Co., New York, 1951, p. 155-189.

A fundamental discussion, with extensive references to the literature. 142 references.—BTR.

3.6.8, 3.8.2

**Investigations on Local-Cell Models Regarding Current-Density Distribution and Modus Operandi (at Electrode Surfaces), Based Upon Measurements of Overvoltage.** K. Durkes. *Z. Electrochem.*, **55**, No. 4, 280-287 (1951).

Investigations on the relation between potential and current density at electrodes in solution of electrolyte, carried out with apparatus comprising local-cell models of the type described by Jaenicke and Bonhoeffer [Z. physikal. Chem., **193**, Series A, 301 (1944)] lead to the deduction that certain conclusions relating to the polarization of platinized platinum electrodes need to be revised. The author finds that, at considerable concentration-polarization, limiting current can exist at small cathodes and at the boundary of large platinized platinum cathodes. Also the current density at large cathodes is limited by processes occurring at the cathode boundaries. Recombination of electrolytically deposited H atoms to form molecules occurs as a process at the boundary regions. It is shown that Ohm's law affords a fair approximation to the electrolytic processes taking place in the local-cell type of apparatus.—MA.

## 3.7 Metallurgical Effects

3.7.3, 3.5.8

**Corrosion Fatigue Resistance of Hollow Axles Increased by Pre-Imposed Compressive Stresses.** H. Buhler. *Werkstatt u. Betrieb*, **84**, 464-466 (1951).

The effect of residual compressive stresses in surface zone of cylindrical steel parts upon their corrosion fatigue behavior is studied. Experimental procedure and results obtained on solid rounds of 0.34 carbon steel subjected to various heat treatments is given. Data on stress distribution favorable for service under conditions involving corrosion fatigue as produced by suitable heat treatment in hollow axles is given. 5 references, graphs.—INCO.

3.7.3, 3.5.8

**Influence of Internal Stresses on Resistance to Alternating Stresses Under Corrosive Conditions.** Hans Buhler. *Metaux; Corrosion-Ind.*, **26**, No. 307, 141-144 (1951).

Buhler shows experimentally that the introduction of superficial compressive stresses into mild-steel test-pieces, by quenching from below the transformation temperature results in improvement in bending fatigue properties both in normal and in corrosive atmospheres.—MA.

3.7.4, 3.2.2

**Role of Crystal Orientation in the Oxidation of Iron.** Earl A. Gulbransen and Roswell Ruka. Westinghouse Research Laboratories, East Pittsburgh, Pa. *J. Electrochem. Soc.*, **99**, 360-367 (1952) Sept.

The interface between a metal and its oxide or other corrosion films is a zone of great interest in the general phenomena of protection of metals. The system of iron and its oxides is considered in this work. Experiments are made using the electron diffraction high temperature camera on the oxidation of single crystals of iron. Definite orientation effects are found between the metal and the oxide if the oxidation is carried out slowly, for example, in a 50 percent water, 50 percent hydrogen mixture at 750°C or in high vacuum. Rapid oxidation that the original orientation effects are not carried through to thick films.

The orientation effects are interpreted in terms of two principles: a) the conservation of similar repeat distances in the two lattices and b) conservation of atom density. The effects of the forward and reverse solid phase reaction $Fe_3O_4 + Fe \rightarrow 4FeO$ is studied and it is shown that the orientation effects are carried through to the newly formed oxide. The results are discussed in their relationships to the general phenomena of oxidation and corrosion. (Author.)

## 3.8 Miscellaneous Principles

3.8.2

**The Behavior of Oxygen and Hydrogen at Electrodes.** J. A. V. Butler. "Electrical Phenomena at Interfaces" (Macmillan Co., New York), 1951, p. 204-228.

A fundamental discussion under the following headings: adsorption of oxygen at anodes, electrolytic behavior of hydrogen, and formation of oxide films on noble metals. 138 references.—BTR.

3.8.2

**Electrical Potential Differences and Their Origin.** J. A. V. Butler. "Electrical Phenomena at Interfaces" (Macmillan Co., New York), 1951, p. 1-29.

A fundamental discussion, with extensive references to the literature. Includes section on electrode potentials of metals. 30 references.—BTR.

# 4. CORROSIVE ENVIRONMENTS

## 4.2 Atmospheric

4.2.3, 2.4.4

**The Prevention of Corrosion in Flue Gas $CO_2$ Instruments.** H. C. Bones. Instrument Practice, **5**, 17-21 (1950) Nov.; *J. Iron and Steel Inst.*, **168**, part 4, 441 (1951) Aug.

The corrosion of flue-gas carbon dioxide recording instruments is due to the production of sulfur during combustion of the fuel. The formation of sulfur dioxide and sulfur trioxide, which are dissolved in water from the fuel, produces highly corrosive acids. Two methods of sulfur dioxide removal are described, the more practical being the absorption by sodium bicarbonate. Operating details are given together with a diagrammatic arrangement of such an absorber, incorporated in an Electroflo recorder. Leakages and methods of detection are discussed; emphasis is laid on the need for careful selection of the sampling points.

## 4.3 Chemicals, Inorganic

4.3.2, 4.3.3, 6.5, 3.8.4

**Dissolving Velocity of Metals in Deutero-Electrolytes.** (In English.) *J. Brun. Acta Chemica Scandinavica*, **5**, Nos. 9-10, 1402-1404 (1951).

Experiments dealing with the dissolution of zinc, aluminum, and iron in acids and bases, the hydrogen content of which

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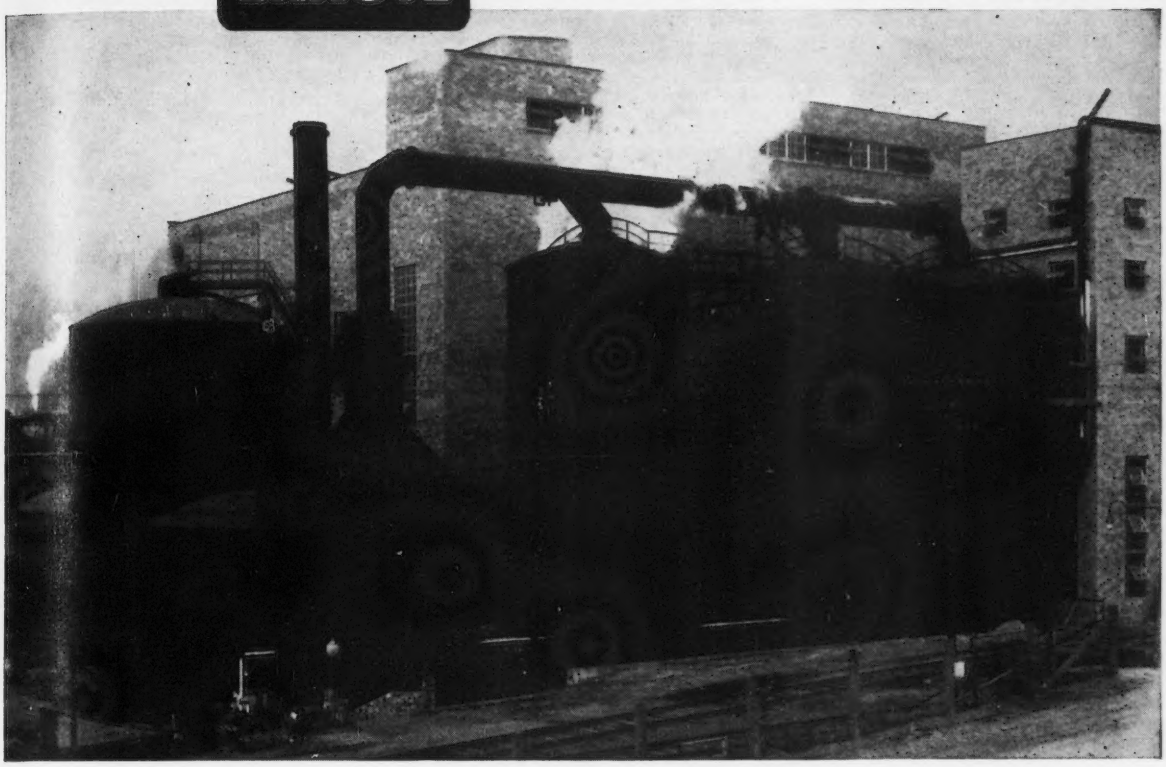

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has been partly or completely replaced by deuterium. Data are tabulated.—MR.

**4.3.2, 7.4.4, 6.5**

**In the Works.** *Chem. Eng. News,* **29,** No. 19, 1882 (1951) May 7.

Vibration and corrosive products combine to shorten the life of a cascade cooler not designed to withstand them. The cooler consisted of two layers of 4-in. Duriron pipe, where nitric acid from the condensers is cooled off. To remedy the vibration from nearby compressors, a new compact design where vibration is not amplified was put into use including an aluminum nitric acid drum constructed of the standard 61S alloy. The pipe conducting hot nitric acid from condensate collector to the cooler was originally of aluminum but was replaced with Duriron. The nitric acid is cooled quickly thereby reducing the corrosion of the aluminum alloy. Only part shownig corrosion after two months of use was the inlet nipple which was aluminum. The acid exit pipe was of stainless steel.

**4.3.6, 6.1**

**Spreading Salts and Their Influence on Street Coatings and Other Materials.** K. Walz. *Werkstoffe u. Korrosion,* **3,** No. 2, 49-54 (1952) Feb.

Sodium chloride, calcium chloride and magnesium chloride are used to remove frost and snow from streets, and concrete is seriously attacked by these salts. Destruction of concrete in practice and in laboratory tests are described, as well as protective measures. Rusting of street vehicles depends on their preservation and upkeep. Laboratory investigations concluded that rubber, leather, and fabrics are not affected by the melted solutions under normal conditions.—INCO.

## 4.5 Soil

**4.5.3, 7.2, 6.6.2, 6.6.5**

**Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe.** Irving A. Denison and Melvin Romanoff. *J. Research Natl. Bur. Standards,* **47,** 367-379 (1951) Nov.

Summarizes results of study made on 2 varieties of asbestos-cement pipe involving exposure to 15 different soils for periods up to 11 years. The soils range from well-aerated types deficient in water soluble salts to very poorly aerated ones containing high concentrations of soluble material. Effects of exposure on mechanical and physical properties are indicated by measurements of hydrostatic bursting pressure, crushing strength, water absorption, apparent specific gravity, and by observations of surface condition of the speciments removed. 10 references.—BLR.

## 4.6 Water and Steam

**4.6.2, 3.5.9, 6.5, 3.5.7**

**Water Corrosion of Structural Materials; October, 1948—June, 1951.** C. R. Breden, S. Greenberg, R. M. Robinson, A. H. Roebuck, V. F. Saitta and C. C Scott. Argonne National Lab., July 15, 1951. 198 p. (ANL-4519).

A program of evaluating the corrosion resistance of materials considered for use in high-temperature water systems has been undertaken. Results of laboratory corrosion tests completed by Argonne and its subcontractors before June 1, 1951, on structural materials other than zirconium are presented. The materials studied include stainless steels, carbon steels and other ferrous alloys, cobalt alloys, nickel and nickel alloys, copper and copper alloys, other metals and alloys, and ceramic bodies. The tests were carried out, for the most part, in high-pressure autoclaves. Of the materials tested, the austenitic stainless, plus the precipitation hardening stainless steels, and high-cobalt alloys were found to be the most satisfactory in 500°F oxygenated water. (Author.)—NSA.

**4.6.2, 5.7.3, 7.6.4**

**Trends in Application of Deaerating Heaters for Boiler Feedwater.** V. J. Calise and R. K. Stenard. Graver Water Conditioning Co. Paper before ASME, Fall Mtg. Minneapolis, 1951. *Combustion,* **23,** No. 6, 41-46 (1951) Dec.

In most boiler feedwater applications, corrosion and pitting of boilers and accessories are caused mainly by the presence of non-condensable gases such as oxygen and carbon dioxide or by low pH in the feedwater. Proper deaeration of feedwater is as essential as removal of scale-forming constituents. Internal construction of the deaerating heaters is of stainless steel to give proper corrosion protection from the acid-treated waters entering these heaters. Diagrams are included—INCO.

## 4.7 Molten Metals

**4.7, 3.5.9**

**The Solubility of Metals and Alloys in Lead-Bismuth Eutectic at Temperatures up to 2200°F.** John F. Collins and H. R. Stephan. April 12, 1951. 14 p. (NEPA-Div.)

A survey of readily available high-temperature alloys and metals was made with respect to their solubility in lead-bismuth eutectic. The temperature range of 900° to 2200°F for times up to 100 hr. was investigated. Selected stainless steels, special alloys, and refractory metals were tested by the agitated-capsule method. Molybdenum, niobium, tantalum, and ingot iron are the most resistant to corrosion by lead-bismuth eutectic. The 18-8 type stainless steels can be used to contain lead-bismuth at temperatures up to 1400°F without excessive attack on the containing material. Type 446 chrome-iron alloy is a better containing material than the 18-8 alloys for applications where structural considerations are not a prime factor. Evidence of selective solubility of nickel and manganese makes the high-nickel alloys undesirable.—NSA.

**4.7, 3.5.9**

**Summary Report on the Solubility of Metals and Alloys in Pure Bismuth at Temperatures Up to 2200°F.** John F. Collins. Apr. 12, 1951. 25 p. (NEPA-Div.)

A survey of high-temperature metals and alloys was made to determine their suitability as containing materials for liquid bismuth. The temperature range of 900° to 2200°F was investigated using the agitated-capsule technique. Molybdenum, iron, and the chromium-iron alloys exhibited the lowest solubility and the least attack by bismuth, nickel alloys with bismuth and nickel bearing alloys had relatively high solubility values at temperatures above 1350°F. The solubility rate appears to decrease with time but saturation conditions were not reached in 500-hr. test periods. Some special tests of ceramics in bismuth and group of service tests are summarized in the appendix.—NSA.

**4.7, 6.2.3, 4.3.5**

**Corrosion of Steel in Molten Sulfur.** A. Dravnieks. Standard Oil Co. *Ind. & Eng. Chem.,* **43,** No. 12, 2897, 2900 (1951) Dec.

Corrosion of steel vessels by hot sulfur-bearing media causes constant difficulties in many industrial processes. Between 300° and 450°C the corrosion of steel in sulfur is limited by two processes, one chemical and another mechanical. A thin film consisting principally of ferrous sulfide grows by diffusion of reactants, presumably iron ions, through the film. The rate of corrosion is inversely proportional to the thickness of the film. With increasing thickness, mechanical strains produce film rupture followed by temporary local acceleration of attack. Kinetic constants of the reaction are given, and the film structure is described. Fundamental mechanisms in sulfide formation on steel in molten sulfur are clarified. This instance of corrosion falls into the type of film-growth reactions complicated by a crack-heating process. Graphs and 14 references are included.—INCO.

# 5. PREVENTIVE MEASURES

## 5.1 General

**5.1**

**Corrosion Research.** *Steel,* **130,** No. 21, 114-116 (1952) May 26.

The future of corrosion problems and work was discussed by H. H. Uhlig, head of the corrosion laboratory at M.I.T., at the Northeast Corrosion Conference in New York. Dr. Uhlig sees application of cathodic protection extended to protect metals against stress corrosion and fatigue. The protection will be provided by metallic coatings. Titanium, he believes, though expensive will be used for cladding steel in hot water tanks to resist pitting and corrosion cracking in chloride containing waters. Titanium cladding will be used on metals exposed to mine and other acid waters. Sacrificial metals will continue to be used. Aluminium can be electrodeposited on copper from an organic bath to give resistance to nitric acid. Aluminum coatings on steel will provide resistance against atmospheres containing sulphur compounds. Increased degree of purification of aluminum and magnesium will result in a 100-fold increase in corrosion resistance. Such purified metals are now being produced by the French. Aluminum will be used to a greater extent in salt water, deactivated of iron and copper salts. In the field of high temperature alloys, an alloy composed of aluminum, chromium, molybdenum and iron will supplement the nickel-chromium alloys.—ALL.

**5.1, 4.1**

**Metallic Corrosion.** W. H. J. Vernon. *Research* (Eng), **5,** No. 2, 54-61 (1952) Feb.

Principles of metallic corrosion, controlling factors in immersed, underground and atmospheric corrosion and their application to the prevention of corrosion

under service conditions are surveyed. The effects of anodic and cathodic oxide films on steels and stainless steel are given. A discussion on corrosion inhibitors includes sodium benzoate, an antifrigerant non-corrosive to steel and sodium nitrite, a good inhibitor towards iron and steel. Measures for prevention of wastage caused by bacteria in iron and steel underground systems are considered. Effects of humidity on the rusting of mild steel and a polished surface of nickel are given. Atmospheric corrosion may be prevented if the tendency of metals, even iron and steel of forming protective films autogenously is encouraged by way of the metal or the environment such as the chromic oxide film of stainless steel. Vapor phase inhibitors are being developed to protect the metal surface of steel. Coatings derived from chemical treatment of the metal as in phosphate coatings of steel are of an intermediate nature. 26 references, illustrations.—INCO.

## 5.2 Cathodic Protection

5.2.1, 8.9.3, 7.5.5

**Cathodic Protection Checks Water Ills.** S. T. POWELL, **96,** No. 3, 71-73+ (1952) Mar.

The theory behind cathodic protection used for protection of pipelines built in corrosive soils and for fresh and salt-water tanks is given. The electromotive series, galvanic action, current density, precleaning surfaces, pipeline protection and recent developments are considered. For external currents electrodes of carbon, graphite, mild steel, Duriron, aluminum, magnesium, and stainless steels are used. Steel vessels of simple geometric shapes like tanks and pipelines are usually furnished with reliable cathodic protection due to the electrode setup. To protect tubes, inner tubes or lines of an aluminum-zinc alloy inside standard aluminum tubes gives galvanic-types cathodic protection system. Iron anodes supported by steel studs are used in the Cumberland process. The Gunderson system used a Duriron anode. The Kerhaldy system is discussed. Illustrations.—INCO.

## 5.3 Metallic Coatings

5.3.1, 5.4.1, 1.6

**Protection and Electrodeposition of Metals.** Department of Scientific and Industrial Research (T.I.D.U.) Book, 1951, 350 pp. *Selected Government Research Reports.* **Vol. 3.** H. M. Stationery Office. £1 10s.

This is a collection of reports, wartime and post war, from the Ministries of Supply and Aircraft Production (now combined as Supply). Under protection of metals, 20 reports appear, covering treatment or corrosion-behavior of aluminium and alloys, magnesium and alloys and steel (a few of these reports have already been published in journals). The section on electrodeposition has 13 papers, including analysis of plating solutions, testing of electrodeposited coatings, and chemical analysis (nearly half of these papers have already been published in journals). This volume is a useful collection, but failure to refer to earlier publication of some of the papers may lead to confusion, and the absence of author and subject indexes is a pity. —BNF.

5.3.2, 4.3.3, 5.9.2

**Hydrogen Evolution from the Tin-Iron Couple in Alkaline Solution.** S. C. BRITTON. *J. Applied Chem.,* **1,** No. 2, S132-S136 (1951) Supplementary Issue.

The corrosion of tin in strongly alkaline solutions is accelerated by contact with iron and may proceed even in the absence of oxygen, hydrogen being evolved from the iron. The degree of acceleration depends on the area of exposed iron. The area exposed at pores in tinplate is likely to have only a very small effect, but in packing alkaline materials in tinplate containers, the use of blackplate ends on the container or the inclusion of metallic iron in the product introduces a risk of pressure development by hydrogen evolution. During the cleaning of tinned ware in alkaline solution, contact of the work with bare steel tank should be avodided It is recommended that containers used for alkaline material should be wholly of tinplate and should, when possible, have an addition of sodium sulfite.—INCO.

5.3.2, 5.3.4

**Corrosion Problems in Connection with Zinc Coatings.** (In Swedish.) U. BOYE. *Iva* (Sweden), **22,** No. 5, 171-174 (1951).

The hot dip and electrogalvanizing of pylons and associated steel parts is discussed. Recommendations are made for the optimum thickness and techniques to secure good adhesion. Reference is made to use of sprayed zinc, with special attention to surface preparation. Other points dealt with include causes of failure, re-galvanizing, effects of bath and surface conditions, and finally the lives of zinc coatings.—ZDA.


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**5.3.2, 6.2.3, 5.3.4**

**The Protection of Steel by Sprayed Aluminium.** W. E. Ballard. *Electroplating and Metal Finishing*, **4**, No. 12, 395-399 (1951).

An explanation is suggested for the formation of the rust stains sometimes appearing on aluminum sprayed steel surfaces. It is stressed that these do not necessarily indicate failure of the coating.—MA.

**5.3.2, 6.4.4**

**Selenium Coatings for the Protection of Magnesium Alloys Against Corrosion.** L. F. Brocq and H. G. Cole. Based on R.A.E. Report, April 1943. Protection and Electrodeposition of Metals-Selected. *Government Research Reports*, **3**, 259-266 (1951) London.

Selenium deposited by a dry method gave as good protection to magnesium alloy sheet to D.T.D. 120A and to propeller blade material as the hot ½ hour chromate bath, and provided an equally good base for paint. To D.T.D. 118 the protection given was inferior to chromate treatment. Selenium deposited from solution, however, gave good protection to D.T.D. 118. Corrosion tests are described, together with fatigue tests to find the effect of selenium films on the fatigue strength of magnesium alloy propeller blade material. Tables.—INCO.

**5.3.4**

**Use of Protective Metallic Coatings.** M. E. Parker. *Oil Gas J.*, **50**, No. 43, 93 (1952) Mar. 3.

Four methods of applying metal coatings are galvanizing, electroplating which is applied to nickel and chromium, spraying process used for nickel alloys including some of the nickel-chromium and nickel-molybdenum hard surfacing materials and deposition of weld deposit. Galvanized steel is used for exposures to atmospheric and water corrosion. The advantages of spraying and welding to apply protective metallic coatings are given.—INCO.

**5.3.4**

**Substituting Znic Oxide for Zinc Cyanide in Plating Solutions.** M. B. Diggin. Metal Finishing (U.S.A.), **49**, No. 2, 64 and 72 (1951) Feb.

A concise note on the making up of zinc plating solutions with zinc oxide instead of zinc cyanide. The equivalent quantities of the two compounds are shown and the method of calculating the necessary extra cyanide to be added is indicated. The substitution of potassium salts for sodium salts is briefly discussed.—ZDA.

**5.3.4**

**The British Wire Process of Metal Spraying.** Ed. C. Butler. *Architects J.*, 113, No. 2923 (1951) March 8.

A description, intended for architects, of the metal spraying gun used for the wire process, together with notes on the structure, adhesion and efficiency of the resultant coating. The most important applications are in the spraynig of zinc and alumnium for anti-corrosive purposes, but other metals may also be deposited by the method.—ZDA.

**5.3.4, 5.3.2, 6.2.2**

**Metallic and non-Metallic Coatings for Grey Iron.** C. O. Burgess. *Foundry* (U.S.A.), **78**, No. 12, 76-79 and 194-203 (1950) Dec.

This first installment deals only with the application and uses of metallic coatings applied by spraying or by hot dipping. The section on sprayed coatings is mainly devoted to those deposited to provide bearing surfaces on castings, and there is only brief reference to the use of zinc and aluminum coatings for corrosion protection. Zinc coatings applied by hot dipping are used to protect a wide range of grey iron castings against corrosion; additional protection by means of chromate treatment is recommended under conditions of high humidity to prevent white rusting. The galvanizing process is briefly described and there are 34 references.—ZDA.

**5.3.4, 6.3.15, 5.9.1**

**Development of Protective Coating for Titanium and Titanium Alloys; June 1-September 30, 1951.** William H. Colner and Howard T. Francis. Armour Research Foundation. (No date) 17 p. (WAL-401-46-4; Interim Technical Report No. 1).

This is a report describing research directed toward development of a method to obtain adherent metallic coatings on titanium by electrodeposition. It was found that methods applicable to stainless steel and aluminum were unsuccessful; in fact, it was concluded that any method based on aqueous solutions showed little promise. Completely adherent deposits were obtained from baths containing zinc chloride, hydrogen fluoride, a limited amount of water, and glacial acetic acid as the solvent. Instability of this bath with time dictated a search for other solvents, since it was felt that the solvent was suffering some polymerization. Ethylene glycol gave equally good results but no improvement in stability. Butyl alcohol and methyl alcohol did not give as good results. (Author.)—NSA.

## 5.4 Non-Metallic Coatings and Paints

**5.4.2, 3.5.9, 6.3.9**

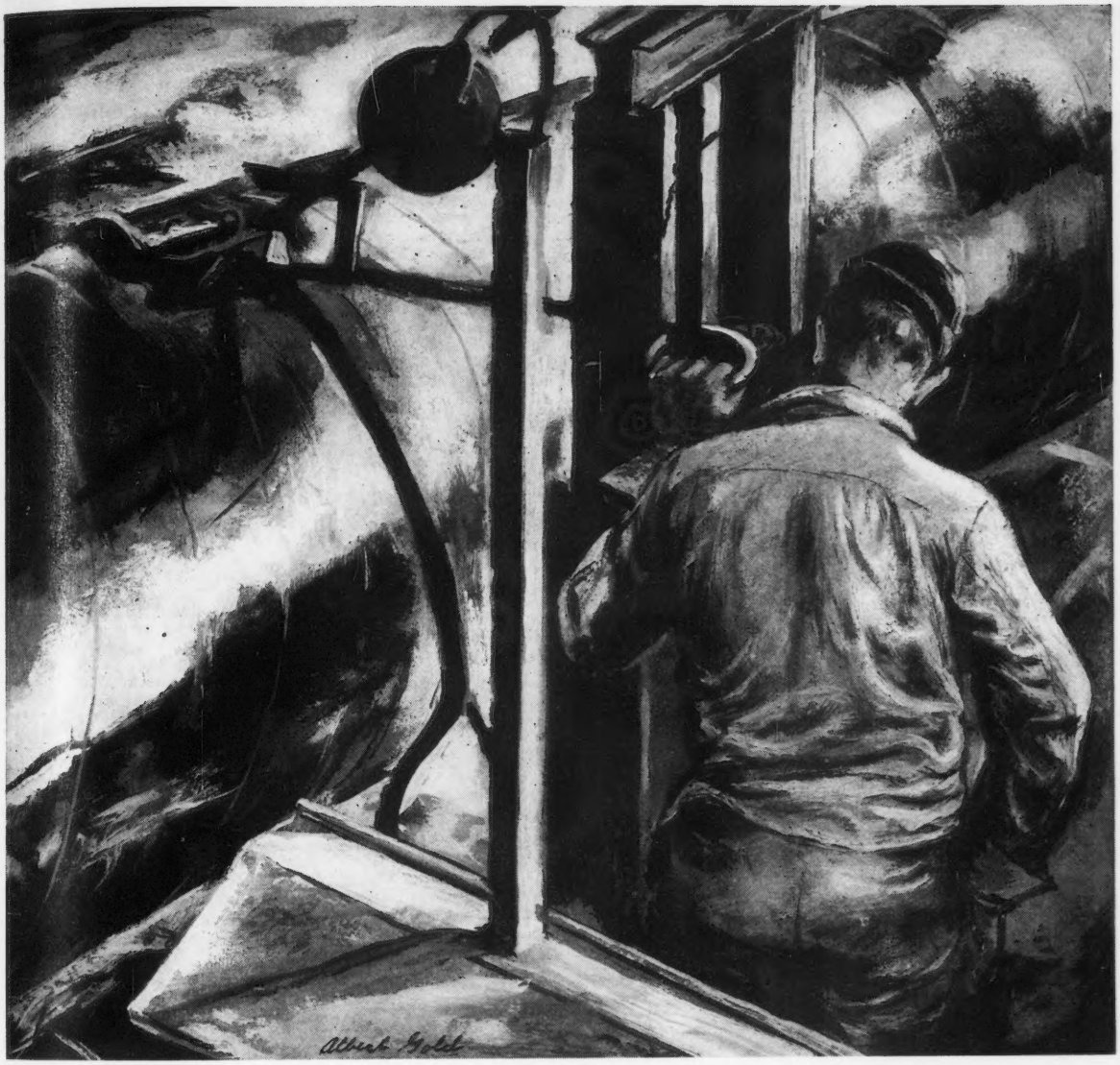
**Ceramic Heat-Resisting Protective Coatings for Molybdenum.** L. G. Davis. *Metall*, **5**, Nos. 15-16, 341 (1951).

Water suspensions and pastes containing zirconium oxide are applied to the molybdenum surface by spraying and dipping processes, and are then baked on at 1175°C in an oxygen-free atmosphere; one or more coatings may be applied. After such treatment the molybdenum is completely unaffected on heating in air for 70 hours at 900°C; oxidation is still appreciably retarded at surface temperature of 1430°C; when subjected to the exhaust gases (at ~ 1650°C) of rocket motors, it has a life of > 45 minutes compared with < 3 minutes for unprotected material.—MA.

**5.4.3, 7.5.5, 4.4.6**

**The Storage Properties of Gasolines in Contact With Water and Tank Wall Materials.** J. Boue, J. Ferrier, and M. Louis. *Rev. Inst. Franc. Petrole Ann. Combustibles Liquids*, No. 6, 305-311 (1951) Aug.

Laboratory and small-scale tests have been made to establish the effects of water nad tank wall materials on the quality of ethyl aviation gasolines. High-octane gasolines containing lead and inhibitors of the aminophenole type show a definite deterioration after prolonged contact with water or concrete. This manifests itself chiefly in a reduction in

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lead contents, octane number, and in an increase in gums. Quantitatively speaking, these effects are of no serious consequence unless the storage involves continued agitation. In practice, aviation gasoline may be safely stored in steel or concrete tanks for several years, even in the presence of fresh or salt water. Some plastic tank hinges, notably those based on organic polysulfides, may show an adverse effect on the gasoline more severe than that encountered with unlined tank walls. Other organic substances, however, are successfully applied as tank linings.—TDD.

**5.4.5**

**Silicones In Protective Coatings.** G. S. Cook and D. W. Kennedy. *Off Dig Federation Paint & Varnish Production Clubs* (U.S.A.), **321,** 629-635 (1951) Oct.

The authors discuss the use of silicone resins in protective coatings, considering those properties which make them superior to other resins, their limitations, formulating technique, pigments which may be used, resins and oil available, and competitive finishes. In choosing a pigment, aluminum powder has the following advantages for the pigmenting of silicone resins: 1. the silicone resins serve as excellent binders for aluminum pigments over a wide rnage of temperatures; 2. silicone resins do not carbonize at high temperatures which will cause blistering and flaking of the film; 3. a silicone resin is suitable for uses where temperatures vary on different areas at the same time; 4. high heat-resistant silicone aluminum coatings are not restricted by the type of metal to be painted. An example of a silicone aluminum paint is the G-E Silicone Suggestion No. 14 having the following ingredients:

| Ingredients | % by weight |
|---|---|
| G. E. SR-61 (60% solids) | 31.2 |
| Aroclor (50% solids) | 37.4 |
| Standard aluminum paste | 22.5 |
| Petroleum spirits | 7.7 |
| 8% zinc octoate | 1.2 |

The paint was formulated with a high aluminum content since heat-resistance over 100°F is primarily a function of the aluminum. Aroclor aids in holding the aluminum powder in the air-dried film and in forming a continuous corrosion-resistant film. When temperatures are in excess of 100°F, the silicone film has gradually decomposed to permit the aluminum to fuse to the metal surface to form a durable metal finish. Aluminum paints prepared with G-E silicone SR-92 are primarily used for the protection of metals during annealing operations.—ALL.

**5.4.5, 2.2.5, 8.9.5**

**Sinclair Evaluates Neoprene Coatings for Tanker Fleet.** W. N. Damonte and T. T. Wilkinson. *Mar. Eng. Ship Rev.,* **56,** 40-47 (1951) Oct. *J. Brit. Shipbuilding Research Assoc.,* **6,** No. 11, 643-644 (1951).

Results of service tests with neoprene coatings on parts of tankers are reported. Particularly good results have been obtained on the main circulator system which previously needed reconditioning every 6-8 years but should now last the lifetime of the vessels. Heat-cured sheet and brushing compounds and air-cured brushing compounds have been used.—RPI.

**5.4.5, 6.2.1, 2.2.2**

**A Study of Primers for Ferrous Metals in an Atmospheric Exposure.** T. A. Dembski, R. Marotta, F. W. Alvarez, E. Berberian, S. A. Fine, R. L. Feffrey, H. Jerome, H. Kelfer, B. J. Mayo, F. S. McIllwaine, W. B. Pierce, S. White, B. Wilson, and E. Zarach. Amer. Paint J. Convention Daily, **36,** 28-29 (1951) Nov. 3.

Results from a five year atmospheric exposure of fifty-six metal primers are presented. Seven primers used on substrata of cold rolled steel have completely failed when exposed without a top coat. Six primers of the fifty-six after identical exposure are still completely intact. These include 52 MC-29 replacing 37% of zinc chromate with graphite mica and a combination of red lead; iron oxide, zinc chromate and leaded zinc oxide in a phenolic vehicle. Results on substrata of hot rolled structural steel angles are substantially the same. Definite conclusions can, therefore, be drawn as to what type of primer will function best as a shop coat and what primers fail in this respect. Correlation of data on the same fifty-six primers with addition of various top coats is still impracticable, since the systems have not deteriorated to a degree where decisive evaluation can be made.—ZDA.

**5.4.5, 6.4.2**

**Protective Power of Chrome Paints on Light Alloys.** C. Bighi and G. Mantovani. *Chimica industria* (Milam), **33,** No. 6, 355-359 (1951).

Tests on aluminum painted with paints containing a) lead chrome and red lead, b) lead chrome alone, c) zinc chrome, and d) red lead showed that red lead gave best protection against dilute hydrochloric acid (0.1 normal and 0.0001 normal) and sodium hydroxide (0.0001 normal). In 3% sodium chloride solution the differences were smaller, and, while red lead was initially good, in time it lost protective power and the compositions containing zinc chrome or a mixture of lead chrome with red lead appeared the best after one month, although lead chrome alone was no better than red lead.—RPI.

**5.4.5, 7.1**

**New Ceramic Coatings for Jet Engine Parts.** Gilbert C. Close. *Finish,* **8,** 27-29, 90-91 (1951) Oct.

Describes and illustrates "Solaramic" process for the above developed by Solar Aircraft Co., San Diego, for applying a vitreous coating as thin as 0.0005 in. to alloy metals with resultant longer life and reduction in critical materials used. Material coated is stainless steel.—BLR.

**5.4.5, 7.1**

**Producing Ceramic Coated Navy Motor Ship Mufflers.** Gilbert C. Close. *Finish,* **8,** 33-34 (1951) Sept.

The above are produced by applying a one-coat heat and corrosion resistant coating to parts ⅛ to 1 inch thick. The coating is mottled deep blue, very hard, and highly resistant to impact.—MR.

**5.4.5, 8.9.3**

**Long Time Performance of Pipeline Coatings.** G. Corfield and C. W. Shupp. *Gas,* **27,** No. 9, 92, 94 (1951).

Extensive field inspections of various types and combinations of underground pipe coatings enabled an analysis to be made of successes and failures, and tentative specifications to be developed for improving the quality of coatings. Quality-control procedures have also been developed and are outlined.—RPI.

**5.4.5, 8.10.2**

**Improved Enamels Extend Life of Steel Chlorination Pipe.** L. E. Dube and N. Stromdahl. *Steel,* **129,** No. 17, 70-72, 99 (1951) Oct. 22.

Slip compositions and firing techniques modified to ease corrosion problem in black pipe used for fluxing and degassing aluminum alloys. Average life of 10 minutes is multiplied 15 to 25 times, within cost limits. Liquid enamel, called "slip," is basically composed of clay, glass and oxides, plus other additions which determine special character. General practice is to apply an initial or ground coat and fire it. The method used to coat the inside is to close one end of the tube, fill it with slip and let it drain slowly. The enamel coating is a two-coat application designed primarily to resist corrosion. The importance of coating cost is discussed.

**5.4.8, 2.1.2**

**Anti-Fouling Compositions. VII—Leaching Rate During the Middle and Late Stages of Compositions Based on Cuprous Oxide as the Toxic Component.** H. Barnes. *J. Iron & Steel Inst.,* **169,** Pt. 4, 360-367 (1951); cf. *Review,* **1949,** 499.

The results are based on leaching-rate studies made in a wide variety of compositions. Of major importance are the cuprous oxide content and the matrix formulation. The latter, with a given cuprous oxide content, determines the leaching rate. With many of the compositions investigated the leaching rates dropped below their "steady" value in the very late stages of soaking. This appears to be caused largely by the building up of a skeletal matrix residue. Methods are suggested whereby formulation can be adjusted to avoid this disadvantage.—RPI.

**5.4.8, 2.7**

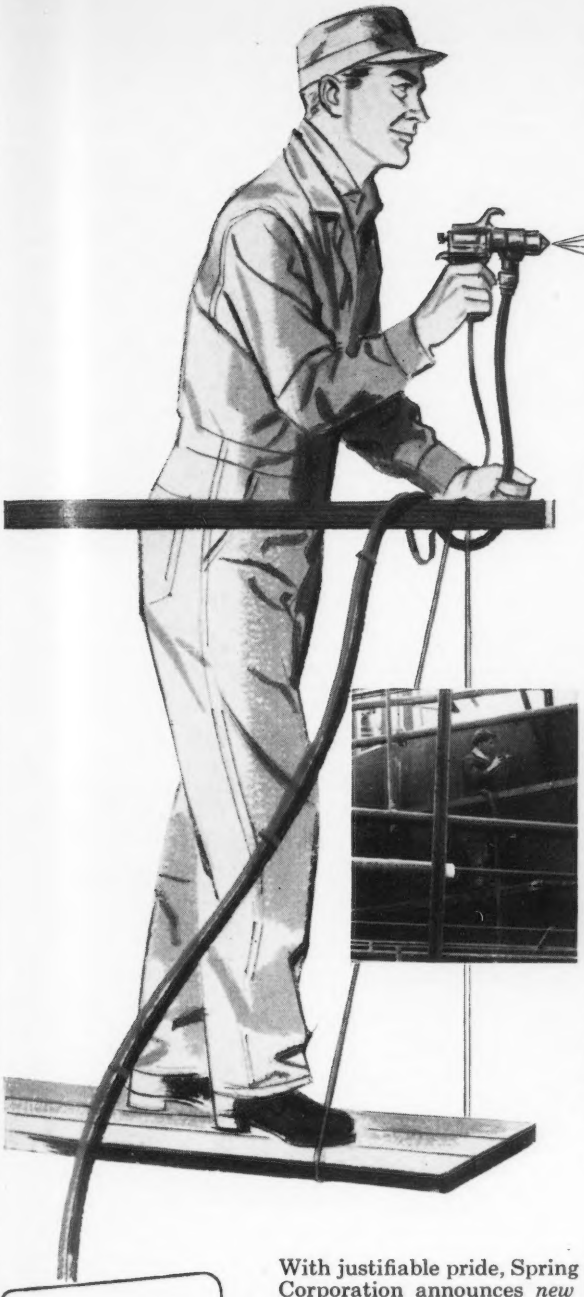
**Fire-Retardant Paints.** T. H. Chisholm and J. W. Suggitt. *Can. Paint & Varnish Mag.,* **25,** No. 5, 26, 28, 66-68 (1951).

Tests have been carried out on a range of fire-retardant paints coated on pine wood and fibre board panels, by two methods, both of which involved burning a given quantity of acetone underneath a specimen, in one case the loss in weight being measured and in the other the degree of flame spread. Coatings based on resin phosphate or sulphanate gave the best fire protection but their washability was poor. Oil paints containing antimony oxide or borax gave fair protection and a smooth readily-washable surface. Silicate paints have good fire protection but had poor washability and film properties. Chlorinated rubber paints gave fair protection with good washability and film properties, but gave off a heavy acid toxic smoke at the fire test temperature. Water emulsion paints incorporating casein, methyl cellulose or alginates, with inert solids in high proportion of lime-cement and similar coatings, had little fire-retardant property. A single coat of oil paint over the more highly fire protective coatings improved washability without interfering with the fire-quenching action.—RPI.

**5.4.8, 4.6.11, 1.7.1**

**Chlorinated Rubber the Best Medium for Marine Anti-Corrosive Paints.** L. B. N. Evans. *Rubber Developments,* **4,** No. 3, 95-98 (1951).

A discussion of the results of the first report of the B.I.S.R.A. committee on



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the formulation of anti-corrosive compositions for ships' bottoms and underwater service on steel (Review, 1950, 623). The paints based on chlorinated rubber were found to be generally superior in a repeat testing of the best eight paints from the original sixty-eight paints tested. Application difficulties and can stability are mentioned as possible disadvantages.—RPI.

**5.4.8, 5.4.5**

**Heat-Retardant Paints and Coatings.** JAMES J. DUGGAN. *Factory Management and Maintenance*, **109**, 101-103 (1951) Nov.

Surveys the above, giving results of 4 series of tests covering steel structural members; steel pipe (empty and water-filled); steel shipping containers; steel-clad wooden doors; and flat steel plates. Results indicate that heat-retardant coatings should be considered for use on all types of structural-steel fire-resistant and non-combustible construction.—BLR.

## 5.5 Oil and Grease Coatings

**5.5.2, 6.2.3**

**Protection of Steel by Different Lanolin Solutions.** S. G. CLARKE AND E. E. LONGHURST. *Selected Govt. Res. Repts.*, **3**, Protection and Electro-Deposition of Metals, Report No. 11, 135-139 (1951).

Tests were carried out on mild steel plates treated by dipping in lanolin solutions of a range of strengths (10, 20, 35 and 50%) in white spirit solvent naphtha and pure benzene. The results of tests and the effects of temperature of application are discussed, tabulated and represented graphically. Benzene solutions deposit the thickest films and therefore give the most effective protection. Cold dipping gives thicker films than hot dipping.—RPI.

**5.5.3, 2.3.5**

**Development of Corrosivity Test for Corrosion Preventive Compounds for Aircraft Bearings.** J. E. CARROLL. U. S. Naval Air Material Center, Philadelphia. Report AML NAM AE 424617, Part II. February 1951, 14 pp.

This study was conducted to develop a satisfactory reproducible, accelerated laboratory test for determining the suitability of oils used for preserving and packaging high speed precision aircraft bearings. Aeronautical documents specify the use of MIL-O-6085 (formerly AN-O-11) Oil; Lubricating, Aircraft Instrument (Low Volatility). Tests of several oils, including some approved under the basic Spec. AN-O-11, showed that some of them failed to protect steel balls in brass retainers when exposed to 80°F and 50% RH for short periods of time. The greaer corrosivity of treated oils over untreated oils in some cases is believed to be caused by a certain undetermined class of sulfonate additives.

Test methods studied included a Galvanic Corrosion Test and a Corrosivity Test. The Galvanic Corrosion Test established a trend but did not provide reproducible results. The test specimen, a Barden #205 steel ball-brass retainer assembly, although simulating an actual bearing, is regarded as unsatisfactory because the history of the specimen is unknown, and because it cannot be refinished easily. Other disadvantages are a 28-day test period and inspection difficulties.

The corrosivity test is reproducible. The test specimen, a brass clip-steel disk specimen, has a known history and it can be treated in any desired way. Examination under a wide field binocular microscope can be carried out quickly and easily. Incorporation of this test into the fourthcoming revision of Spec. MIL-O-6085 is suggested.

These experiments also demonstrated that corrosion is not limited to brass-steel bearings but includes all types of bearings. Rusting is caused by faulty processing of bearing components before a rust preventative is applied as well as by the nature of the additive in the corrosion preventive oils.—PDA.

## 5.8 Inhibitors and Passivators

**5.8.1.**

**Liquid and Vapor Corrosion Inhibitors.** HAYWARD R. BAKER AND WILLIAM A. ZISMAN. U. S. Naval Research Laboratory. *Lubrication Eng.*, **7**, 117-122 (1951) June.

The progress of post-war research on polar type rust inhibitors is reported. Information is summarized on the structure of soaps and amine-acid complexes, the colloidal state of polar compounds in nonaqueous systems, adsorption on metal surfaces, the mechanism of rust inhibition, and the properties of vapor-phase inhibitors.

Soaps (metal salts) and ammonium salts of high-molecular weight acids act as rust inhibitors in oils through the release of associated organic acid. The most effective rust-inhibiting additives are those able to remain in the most highly dispersed colloidal condition and to supply the organic acid having the greatest ability to inhibit steel. The most potent inhibitor acids are those forming iron soaps *in situ*. These soaps are believed to be deposited as chemisorbed molecular monolayers; there is no conclusive evidence that rust inhibitors absorb as polymolecular films on steel. Soaps formed *in situ* have not been shown to be identical with those made in bulk and added to the oil. The relative advnatages and disadvantages of soaps nad amine-acid complexes as rust inhibitors can be outlined in terms of their relative acid-associating tendencies, their reaction with nonferrous metals, and the effect of temperature.

The effectiveness of substituted ammonium nitrites as vapor-phase inhibitors is explained by their simultaneous display of two independent rust inhibiting properties, viz., the ability of the organic end of the molecule to form a hydrophobic adsorbed monolayer or water barrier, and the ability of the polar nitrite end of the molecule to inhibit corrosion by passivating the underlying steel surface. A bibliography of forty references is included.—PDA.

**5.8.2**

**Good Capacity for Absorbing Carbon Dioxide Makes Amine Useful in Corrosion Inhibiting Formulations.** *Chem. Processing*, **14**, No. 1, 20 (1951) Jan.

The properties and physical constants of cyclohexylamine and dicyclohexylamine are given and the usefulness of these compounds in petroleum additives, corrosion inhibitors and inorganic synthesis emphasized.

**5.8.2**

**Corrosion Inhibiting Wax.** *Chem. Eng.*, **58**, No. 5, 202, 204 (1951) May.

A new non-toxic corrosion inhibitor, called Industrial Wax W-6119, meeting government specification on the manufacture of food handling equipment, gives needed protection to many types of food handling equipment, including utensils, stoves, refrigerators, immersion heaters, baking ovens, etc. It can be applied by conventional dips, spray or brush methods to all types of metals. Vapor degreasing removes it. Mfd. by S. C. Johnson & Sons, Inc.

**5.8.2., 1.3, 8.4.3**

**Inhibitor Control for Sulfide Corrosion.** J. A. CALDWELL, Humble Oil and Refining Company. *World Oil*, **132**, No. 5, 191 (1951) April.

The author reviews the results of liquid inhibitor tests in wells with previous histories of many equipment failures and demonstrates the effectiveness of inhibitor use where the corrosion control cost is limited. The composition of the liquid inhibitor developed by Humble Oil and Refining Company is not given. —NALCO.

**5.8.2, 5.4.8, 6.6.11**

**Wood Preservatives.** H. C. BRYSON. *Paint Manuf.*, **21**, No. 7, 258 (1951).

Copper oleate is an effective wood preservative. Its action is greatly increased by a trace of mercury.—RPI.

**5.8.2, 8.8.1, 4.6.1**

**Corrosion Problems Arising from Water in Chemical Industry.** U. R. EVANS. Paper, Soc. Chem. Ind. Meet., London, July, No. 12, 1951. *Chemistry & Industry*, No. 53, 1193-1200 (1951) Dec. 31.

Corrosion by cooling waters may be effectively combatted by use of adequate amounts of anodic inhibitors, including nitrites, chromates, phosphates and emulsifying oils. The amount needed increases with the chloride content of the water. If the inhibitor becomes locally exhausted, the corrosion attack may be more severe than if no inhibitor had been added. Badly designed plant (containing inaccessible corners) or careless operation leading to accumulation of debris increases the danger of local exhaustion and intensified corrosion; the use of phosphate-chromate mixtures or the new benzoate type of inhibitor diminishes this danger. Corrosion by boiler water includes pitting caused by oxygen, pitting of the type connected with metallic copper in laminate scale and also caustic cracking. For preventing the latter, the sulphate ratio rule is of questionable utility, but the Purcell-Whirl controlled phosphate process deserves attention.

**5.8.4, 3.3.2, 7.1**

**Prevention of Corrosion in Inactive Strut and Stern Tube Bearings.** JOHN W. CADORETTE. U. S. Naval Engineering Experiment Station, Annapolis. Report 1A066744 January 1951. 14 p.

Corrosion and marine growth in submerged, water-lubricated stern-tube and strut bearings of inactive Naval vessels is a serious problem. The possibility of preventing this danger by enclosing the bearings in boots filled with a water-soluble inhibitor was studied by immersing eight types of stern-tube and strut bearings in six inhibiting solutions for three months. To simulate leakage

that can be expected with boot seals, 40% of each solution was removed each week for the first six weeks and replaced with synthetic sea water.

The results of this short-term test showed that chromate and nitrite solutions are promising inhibitors. A chromate-caustic-brine mixture is ineffective; hexametaphosphate and metasilicate are unsuitable for use in sea water; and ethylene glycol antifreeze damages rubber bearings.

The inhibitor concentrations used were 10,000 ppm sodium chromate, sodium hexametaphosphate, and sodium metasilicate; 60,000 ppm sodium nitrite; a mixture of 1.5 lb sodium chromate, 0.3 lb sodium hydroxide, and 90 lb sodium chloride per 100 gal water; and 50% commercial ethylene glycol antifreeze.

5.8.4, 4.3.2, 2.3.4

**Corrosion Inhibitors for Mild Steel in Hydrochloric Acid.** E. A. BRIED AND H. M. WINN. 7th Conf. of Natl. Assoc. Corrosion Engineers, New York, 1951. *International Chem Eng. Process Inds.*, **32**, No. 6, 279-280 (1951).

The development of a rosin amine adsorption inhibitor for HCl used for cleaning steel is described. The solubility of the rosin amine in the acid is effectively increased by condensing with ethylene oxide, the optimum reactant ratio being five moles of ethylene oxide per mole of rosin amine in conjunction with 15% free amine. (See *Corrosion*, Vol. 7, No. 6, 180-185 (1951) June.—RPI.


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## 5.9 Surface Treatment

5.9.1, 2.1.2, 1.3

**Metal Finishing Developments in 1951.** W. A. RAYMOND. *Metal Finishing*, **50**, No. 1, 50-56 (1952) Jan.

A discussion of electropolishing, pickling, metal plating including nickel, anodic and conversion coatings, special surface temperatures, testing and analysis, equipment, and cleaning and degreasing. 102 references.—INCO.

5.9.2, 3.4.3, 7.6.4

**After-Deposits Resulting From Chemical Cleaning Process.** P. H. CARDWELL. *Combustion*, **23**, 67-68 (1951) Dec.

Presents a study on the amount and type of the above. Causes for corrosion on the internal metal surface of the boiler are discussed.—BLR.

5.9.2, 5.8.2, 6.2.3

**Methods of Removal of Corrosive Perspiration Deposits from Steel.** S. G. CLARKE AND E. E. LONGHURST. Selected Govt. Res. Repts., Vol. 3, *Protection and Electro-Deposition of Metals*, 1951, Report No. 9, 127-134.

Aspects dealt with are: a) the degree to which ordinary degreasing with trichlorethylene will remove sweat residues, b) the efficiency of methyl alcohol in comparison with other materials, since this solvent has certain potential objections, e.g., toxicity. Substances tried were: ethyl alcohol, methyl ethyl ketone, oils, and water with and without soluble oils and other anti-corrosive additions. Finger-marks on steel can cause marked


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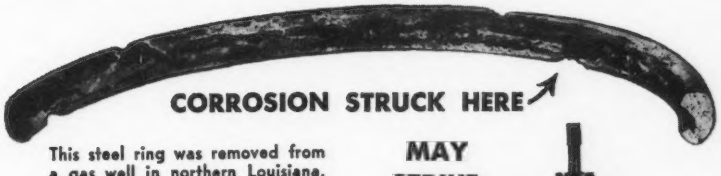

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corrosion of unprotected steel. Laboratory tests of some 20 possible removers of the corrosive material showed the following as capable of giving satisfactory results: methyl alcohol certain neat soluble oils followed by washing, certain soluble oil emulsions used hot, water with suitable inhibitor used hot or cold or in conjunction with a water displacer. —RPI.

5.9.2, 6.4.2

**For Better Finishes Clean Aluminum Thoroughly.** *Steel*, **130**, No. 6, 88-92 (1952) Feb. 11.

An aluminum surface coated with oil must be solvent precleaned prior to any etch cleaning operation. Vapor degreasing using chlorinated solvents will in itself suffice as cleaning pretreatment in some cases, or as a pretreatment prior to alkali cleaning in plating cycles. Solvent emulsion cleaning is used with aluminum parts in spray washing machines. Alkali cleaners are of two types: etching and non-etching. Finer etches are produced with the more strongly alkaline solutions and coarser etched surfaces with the milder alkalis. Removal of smut remaining on the aluminum surface after etching can be accomplished by a combination of nitric and hydrofluoric acids. Non-etch cleaners contain alkalis, wetting agents and an inhibitor to prevent attack on the aluminum. Inhibited cleaners consist of tetrasodium pyrophosphate with an inhibitor such as sodium metasilicate. Sodium phosphate or trisodium phosphate may also be used. Phosphoric acid type cleaners are used for cleaning aluminum parts prior to organic finishing. These do not form a smut. This type of cleaner is valuable for cleaning large objects which cannot be immersed in the cleaning solution. An effective acid cleaning treatment for removal of the natural oxide film consists of a hot etch in 25% (by weight) sulphuric acid for 5 minutes at about 180°F. This may be followed by a dip in 1:1 nitric acid. The oxide film on the metal surface must be removed prior to spot welding. A solution consisting of 9 ounces per gallon phosphoric acid and 2¾ ounces per gallon of chromic acid can be used. A hydrofluoric acid (1 per cent) immersion is sufficient. One firm recommends that aluminum being treated for spot welding should go immediately from the rinse tank, after cleaning, into the deoxidizing solution. Photographs show: 1) aluminum boat hulls being cleaned prior to painting 2) Overhead monorail equipment and wire baskets used to move stamped parts through cleaning cycles at Reynolds Metals Co. 3) Automatic five-stage cleaning and alodizing machine for treating aluminum sheets prior to painting and 4) Deoxidizing Alclad aluminum at Lockheed Aircraft Corp. before spot welding, using a steel processing tank protected by an acid proof brick lining and heated with a carbon electric unit.—ALL.

5.9.2, 6.4.4

**Treatment In Cold Chromate Baths of Magnesium Alloy Parts Previously Treated in the Acid Chromate Dip and Lanolined.** H. G. Cole and E. Parry. R.A.E. Technical Note, January 1946. *Selected Government Research Reports* (England), **3**, Protection and Electro-Deposition of Metals, pages 67-71, H.M.S.O., London 1951.

Experiments were made on methods of chemical cleaning of magnesium alloy parts prior to chromate treating in cold electrolytic and cold immersion baths. The parts had already been treated in the acid chromate dip and then lanolined. It was found that when magnesium alloy parts are to be chromate treated in the cold electrolytic bath or the cold immersion baths it is advisable to remove existing chromate film completely, e.g., by mechanical abrasion with pumice powder. If the parts are coated with lanolin, a preliminary organic degreasing treatment and a final degreasing in an aqueous alkaline metal cleaner are also advisable. Cleaning by chemical methods which do not completely remove the previous film, such as organic degreasing followed by immersion in the alkaline metal cleaning solutions or caustic soda, are liable to affect adversely the appearance and protection of the final chromate film.—ALL.

5.9.4

**Corrosion by Retained Treatment Chemicals on Phosphated Steel Surfaces.** S. G. Clarke and E. E. Longhurst. *J. Iron Steel Inst.*, **170**, Pt. 1, 15-18 (1952) Jan.

Results are presented of humid-atmosphere corrosion tests, which show that small amounts of the treatment solution that may be retained on the surface after phosphating steel by plain phosphoric acid/metal phosphate phosphating processes are relatively innocuous. This is not always so when the phosphating solution contains accelerating agents; efficient washing-off may then be required. A simple performance test is suggested as a guide if the corrosive tendency of a phosphating solution is not known or if the geometry of the parts treated makes effective washing difficult. Tables and three references are included.—RPI.

## 6. MATERIALS OF CONSTRUCTION

### 6.4 Non-ferrous Metals and Alloys—Light

6.4.2, 4.4.2

**Corrosion of Aluminum and Aluminum Alloys by Citric Acid and Citric Acid-Salt Solutions.** J. M. Bryan. *J. Sci. Food Agr.*, **1**, No. 3, 84-85 (1950).

The corrosion rate of four grades of aluminum (99 • 25-99 • 993%); Al-Mn (1•78%), Al-Mg-Mn (1•78-0•45%) alloys by 0•1 N-citric acid I) under static conditions is approx. doubled per 10°C rise in temperature. Addition of 0•1 N-sodium chloride II) produces pronounced rate increases at 25°C, but has little effect between 60° and 95°C. At 95°C the sodium chloride has little effect. The corrosion rates of 99•25% aluminum and of the two alloys in I) are only slightly increased by agitation. In II), agitation shows a pronounced effect. —MA.

6.4.2, 4.6.1

**Aluminum and Water.** (In German.) M. Schenk. *Metalloberflache, Ausgabe B.*, **4**, No. 3, B33-B36 (1952) March.

Role of oxide film; electrochemical nature of corrosion; corrosion products: Corrosion resistance of aluminum to various types of water, such as rain water, fresh water, sea water, and distilled water. Reasons for the existence of corrosion resistance; nature of the different types of corrosion; and the main constituents likely to be harmful to aluminum.

6.4.2, 3.2.2

**The Causes of the Localized Character of Corrosion of Aluminum.** C. Edeleanu and U. R. Evans. *Trans. Faraday Soc.* (England), **47**, pt. 10, 1121-1135 (1951) Oct.

The pitting and localized attack on aluminum is explained by the autocatalytic character of the anodic corrosion reaction; theoretical considerations suggest that if once, at a point, the anodic current density becomes high, it will tend to rise higher, until checked by the evolution of hydrogen, which tends to produce a film of oxide or hydroxide over the point and slow down the reaction. Pitting may be expected to occur on aluminum in neutral solutions and on iron in alkaline solutions as is found to be the case. The theoretical reasoning is supported by observation of pH changes around corroding specimens and also in divided cells, as well as by experiments on the corrosion cracking of aluminum-magnesium in a susceptible state. (Authors' summary.)—ALL.

6.4.4, 2.3.2, 5.9.4

**Corrosion Problems in Magnesium and Its Alloys.** J. Akerlund. *Iva*, **22**, 157-163 (1951).

Magnesium alloys have a bad reputation for corrosion resistance as shown by their sparing use in construction, a reluctance resulting from experience with chloride salt inclusions due to faulty casting techniques. Results of drastic salt water and salt atmosphere testing methods also contribute to this distrust. Modern problems arise from the presence of damaging elements such as iron, which, above 0.017% causes a sharp rise in corrosion rate. Earlier work is reviewed briefly on the use of manganese as a protection against iron, as well as anodizing with chromic acid and treatment with a solution of 4% potassium dichromate and 6% magnesium sulphate at 100°C.—EL.

6.4.4, 3.5.8, 6.7.3

**On the Stress Corrosion on Magnesium Alloys.** L. G. Davis. *Metall* (Germany), **5**, Nos. 17, 18, 392-393 (1951) Sept.

Tests have been carried out by the U. S. National Bureau of Standards on rolled and pressed magnesium samples fabricated of different alloys. The rolled samples were made of the alloys: Ml, AZ31X, AZ51X, AZ61X, and a plated alloy in which the core of AZ31X was placed between two layers of Ml alloy. The pressed samples were made of Z-60, AZ61X, AZ80X, and AZ80X-HTA. The tests were on the whole carried out according to ASTM's standardized samples for tensile testing. The samples, some tension free, some under tension stress were placed inland as well as in maritime atmospheres. Also laboratory tests were carried out with a sodium chloride-calcium chromate solution and alternate dipping in a 0.01 percent sodium chloride solution. The stress corrosion resistance of magnesium alloys decreases with the increase of aluminum content up to 6.5 percent aluminum. The samples under tensile stress proved more resistant to corrosion in maritime atmospheres than inland, whereas the stress free samples showed good corrosion resistance inland. Most corrosion resistance of the alloys tested proved to be the Ml plated AZ31X alloy. The rolled Ml-h, ZK60, AZ31-h, and heat treated AZ80X proved resistant, whereas AZ51X,

and non-heat treated AZ80X showed little stress corrosion resistance.—ALL.

6.4.4, 3.7.2

**Preparation of High Purity Magnesium and a Study of the Effect of Non-Metallic and Alkali Metal Impurities of the Corrosion Characteristics of Pure Magnesium.** Biennial Report (December 1, 1949—November 30, 1951); Dow Chemical Co. (No date) 94 p.

Data are reported from studies of the corrosion properties of the pure magnesium binary alloys with lithium, barium, strontium, potassium, sodium, calcium, silicon, carbon, chlorine, nitrogen, oxygen, phosphorus, and iron. The investigations disclosed that none of these elements was detrimental except sodium, calcium, iron, and possibly carbon. However, there were indications that carbon, chlorine, and silicon are very detrimental if small amounts of iron are present. Phosphorus was found to be beneficial if critical amounts of iron were present. The benefits of phosphorus were also observed in the magnesium-iron-aluminum alloys. A review of procedures involved and a discussion of results obtained in the purification of magnesium by vacuum sublimation are included.—NSA.

6.4.4, 3.7.2

**Preparation of High Purity Magnesium and a Study of the Effect of Non-Metallic and Alkali Metal Impurities of the Corrosion Characteristics of Pure Magnesium;** 7th Quarterly Report; June 1, 1951-August 31, 1951. Dow Chemical Company. (No date) 46 p. (COO-78).

Phosphorus improves the corrosion resistance of magnesium-iron alloys in the "as cast" state when the iron content is above the tolerance limit of 80 ppm. At low iron values there may possibly be a slight detrimental effect due to phosphorus. A high-temperature solution heat-treatment with water quench noticeably improves the corrosion resistance of both magnesium-iron and magnesium-iron-phosphorus alloys when the iron content is above the tolerance limit. Photomicrographic studies have confirmed the existence of a maximum in the plot of corrosion rate vs. iron content in magnesium-iron binary alloys. The maximum is caused by wide dispersion of iron in magnesium. A comparison of commercially pure magnesium and sublimed high-purity magnesium was made in the following corrosion medium: 1 normal hydrochloric acid, acetic acid + sodium acetate, 1 normal hydrochloric acid +3% sodium chloride, and 3% sodium chloride. The high-purity magnesium exhibited greater corrosion resistance than the commercially pure magnesium in all cases except the acetic acid-sodium acetate solution.—NSA.

6.4.4, 3.7.2

**Preparation of High Purity Magnesium and a Study of the Effect of Non-Metallic and Alkali Metal Impurities of the Corrosion Characteristics of Pure Magnesium;** 6th Quarterly Report; March 1, 1951-May 31, 1951. Dow Chemical Company. (No date) 30 p. (CQO-47).

In the production of high-purity magnesium as free as possible of both metallic and nonmetallic impurities, as well as in the evaluation of the corrosion characteristics of this metal, a number of melts of pure magnesium were made with additions of the following impurities: $Mg_2C_3$, grease, lithium, barium, strontium, potassium, sodium, calcium, silicon, manganese, and iron. Of all these contaminants only iron and calcium showed definitely detrimental effects (in the concentration range studied) as evaluated by alternate immersion in 3% sodium chloride. The corrosion results of carbide contamination were erratic and are still inconclusive. The tolerance limit for iron in magnesium is observed at 0.008% rather than 0.016 as previously reported by Hanawalt et al. This difference is attributed to the increased accuracy of the spectrographic analysis for iron as currently practiced. A maximum in the corrosion rate curve is also observed at the critical iron concentration of 115 to 270 ppm. Magnesium has been produced free of magnesium oxide in the sublimation-vacuum casting unit as evaluated by electron-diffraction analyses.—NSA.

6.4.4, 3.7.2, 8.9.1, 3.5.9

**Magnesium Rare Earth Alloys.** J. W. Eastwood. Battelle Memorial Inst. *Product Eng.*, **22**, No. 9, 158-161 (1951) Sept.

Cast alloys containing up to 6% rare earths and wrought alloys with about 2% rare earths have high creep resistance at 600°F. The magnesium rare earth alloys were developed in Germany and are referred to as EM22, EM42, and EM62. A study of the magnesium rare earth alloys was sponsored by the Air Force and NACA to improve their foundry characteristics and to increase the load capacity of the wrought alloys in the range from 500°-600°F. Two magnesium base compositions, a cast alloy containing 6.0 rare earths, 0.9 manganese, 0.20 nickel and 0.01 tungsten and a wrought alloy composed of 2.0 rare earths, 1.5

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manganese and 0.20 nickel were developed during the investigation. The rare earths consisted of approximately 50 cerium, 25 lanthanum, balance rare earths with 1.0 iron. Average properties for experimental and cast alloys are compared with other cast and wrought alloys. Intended use for the two experimental alloys is for cast and forged parts of air-craft engines and for airframe parts operating at 500°-600°F. In such applications, standard methods of surface protection are necessary because corrosion resistance of the new alloys is relatively low, especially in marine atmospheres. —INCO.

6.4.4, 5.4.2

**A New Finish for Magnesium Alloys.** HARRY A. EVANGELIDES. *Metal Finishing*, **49**, 56-60 (1951) Oct.

Describes HAE coating recently developed at Frankford Arsenal. It is produced by an electrolytic process and is ceramic and refractory in character. Corrosion-test results are described and illustrated.—BLR.

## 6.6 Non-Metallic Materials

6.6.5, 4.3.2

**Acid-Resistant Cements.** (In German.) KARL DIETZ. *Werkstoffe u. Korrosion*, **2**, 446-448 (1951) Dec.

A new potassium silicate cement "Hoechst HFR" is described. It is said to have very high adhesive strength, chemical inertia towards chromium-nickel steels and lead, high corrosion resistance to fluorine compounds in ceramic linings, ease of application, and resistance to strong hot acids (except HF).—BTR.

6.6.6

**The Nature of Sulfate Corrosion.** (In German.) RUDOLF RASCH. *Sprechsaal fur Keramaik—Glas—Email*, **85**, 28-29 (1952) Jan. 20.

In discussing the above, it is shown that corrosion of glass-tank refractories does not occur at places of highest temperature. Illustrations and charted data. —BTR.

6.6.7

**Rubber in Chemical Engineering; Specialized Uses for Synthetics.** *Chemical Age*, **65**, 767-770 (1951) Dec. 8.

Discusses the versatility of rubber and its allied products. Gives properties and applications of various synthetic formulas and cites advantages and difficulties. —BLR.

6.6.8, 5.1

**Corrosion Prevention; Changing Techniques in Synthetic Resins.** *Chemical Age*, **65**, 189-192 (1951) Aug.

The role of synthetic resins in the field of corrosion prevention. Major categories are bonding agents for brick linings in tanks; cement for floor construction; and surface coatings for metalwork and concrete.—MR.

## 6.7 Duplex Materials

6.7.2, 3.5.9, 3.7.2

**Fundamental Properties of Metal-Ceramic Mixtures at High Temperature.** Periodic Status Report No. 27. W. B. CRANDALL, Director. Alfred University. July 31, 1951, 7 p. (NP-3243).

Preliminary thermal shock experiments have been conducted on a number of porcelain balls, one group having porosity of 12% and the other having a zero porosity, to determine the validity of the theory. Using the zero-porosity balls, a fine hairline crack instantly propagated causing complete fracture. In the higher porosity balls fine hairline cracks were very difficult to detect. Thus a statistical approach seems necessary. It was found that the structure of the aluminide intermetallics (nickel-aluminum, chromium-aluminum, and molybdenum-aluminum) are too complex to be determined by simple x-ray diffraction powder techniques. A method is described for obtaining solid-state diffusion curves using radioactive tracers.—NSA.

6.7.2, 3.5.9, 3.7.2

**Elevated Temperature Properties of Titanium Carbide Base Ceramals Containing Nickel or Iron.** A. L. COOPER AND L. E. COLTERYAHN. Lewis Flight Propulsion Lab., National Advisory Committee for Aeronautics. Dec. 3, 1951, 47 pp. NACA-RM E51110.

Elevated-temperature properties of titanium carbide base ceramals containing nickel or iron were determined in oxidation, modulus of rupture, tensile strength, and thermal-shock resistance. Metallographic structure was studied. These materials followed the general growth law and exhibited two stages in oxidation. The following tensile strengths were found at 2000° F: 13.3 weight percent nickel, 16, 150 pounds per square inch; 11.8 weight percent iron, 12,500 pounds per square inch; unalloyed titanium carbide, 16,450 pounds per square inch. Nickel or iron additions to titanium carbide improved the thermal-shock resistance, nickel more. The path of fracture in tensile and thermal-shock specimens was found to progress approximately 50 percent intergranularly and 50 percent transgranularly.—NSA.

# 7. EQUIPMENT

## 7.5 Containers

7.5.4, 5.4.5, 5.3.2, 4.2.1

**Metallizing Method of [Gas-] Holder Protection Used at Long Beach, Calif.** ARTHUR ROHMAN. *Am. Gas J.*, **172**, No. 3, 17-18, 46 (1950).

Experiments are described using various paints and metallizing treatments for the corrosion protection of gas-holders in an atmosphere that is both marine and industrial. Full details of the guns used and the final inspection procedure carried out are given.—MA.

## 7.8 Wires and Cables (non-electrical)

7.8

**Proper Lubrication Lengthens Wire Rope Life.** J. P. CRITCHLOW AND R. W. FLYNN. Paper before Am. Soc. Lubrication Engrs., Ann. Mtg., Philadelphia, 1951. *Steel*, **128**, No. 26, 110-112+ (1951) June 25.

Wire rope with core and each strand lubricated withstood 9 times as much pulsating load on testing than did rope without lubrication, and 2.5 times as much as rope with only the core lubricated. Rope must be lubricated at the factory and again in the field. Rules for suitable lubricants, testing procedures, relubrication, and causes of failure other than lubrication are discussed.—INCO.

## 7.10 Other

7.10, 2.1.3, 6.2.5, 5.3.2

**The Stability of Analytical Weights, Particularly in Chemical Laboratories.** P. H. BIGG AND F. H. BURCH. *Brit. J. Applied Phys.*, **2**, 126-131 (1951) May.

Work at NPL, in which analytical weights of various types were submitted to accelerated corrosion and stability tests in representative chemical laboratories. Materials were austenitic stainless steels (25/20 and 20/10, 80-20 nickel-chromium alloy, brass (Delta metal), brass weights plated with, varying thicknesses of platinum on silver on copper, varying thicknesses of platinum, varying thicknesses of rhodium on silver on copper, varying thicknesses of rhodium, and varying thicknesses of chromium on nickel. As regards stability of mass, little to choose between austenitic stainless steel 25/20, 80-20 nickel-chromium alloy and plated weights having nominal thickness of plating about 0.015 mm, or more; some weights of specially polished stainless steel were, however, slightly superior. Chromium plated weights retained appearance better than any except those of highly polished stainless steel and nickel-chromium alloy, but underlying nickel was slightly magnetic, which is objectionable. Includes information on behavior of weights of various materials under good conditions. Lead should not be used in adjustment of weights.—INCO.

# 8. INDUSTRIES

## 8.1 Group 1

8.1.2, 5.3.4, 5.4.8

**Protection of Structural Steelwork Against Atmospheric Corrosion.** Discussion on paper by J. C. HUDSON AND W. A. JOHNSON. *J. Iron Steel Inst.*, **170**, No. 2, 153-156 (1952) Feb.

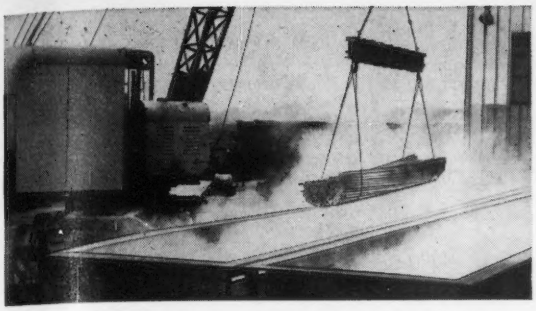
The discussion on a paper reported earlier. [*J. Iron Steel Inst.*, **168**, No. 2, 165-180 (1951) June]. In introducing part I, Hudson mentioned that the lives of hot dip galvanizing coatings on electricity pylons agreed well with his results, as in rural areas a 2 oz. zinc coating lasted 15-20 years before painting was necessary. He later mentioned that B.I.S.R.A. exposure racks were now protected against corrosion either by hot dip galvanizing or by sprayed aluminum.—ZDA.

## 8.3 Group 3

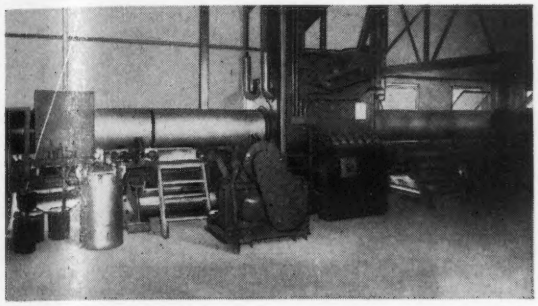
8.3.5, 4.6.11

**Report on Corrosion Problems of the West Cape Coast Fish Meal and Canning Factories.** W. J. COPENHAGEN (Div. Chem. Services) and L. WHITBY (Paint Industries' Res. Inst.) South Africa, Div. Chem. Services, July 1951, 18 pp.

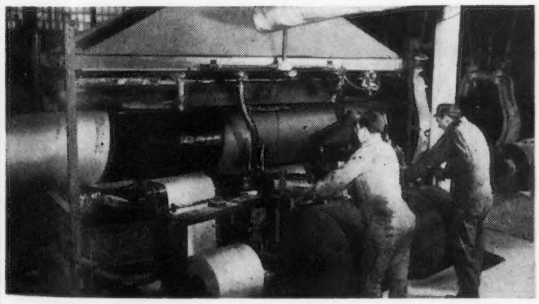
Apart from specific cases of corrosion enumerated, severe general corrosion occurs on most of the metal work in the fish canning sections of the factories. In such sections sea water is liberally used for washing-down purposes, and this, together with much escaping steam, causes a highly aggressive environment. Exhaust boxes, retort cages, steam pipes and retorts suffer extreme corrosion. Various external protective paint treatments were used on oil storage tanks of mild steel plate and, with few exceptions, the metal was found to be in good condition. Preparation of new steel



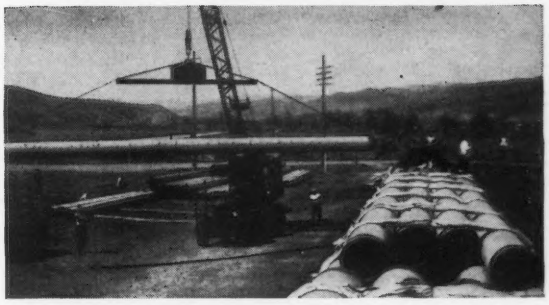
HOT CAUSTIC DIP removes all cutting oil and grease. Pipe is then rinsed in clear, hot water and dried in warming room. Throughout Hill, Hubbell process, pipe is kept at 80-90° to prevent moisture condensation.



ROTO GRIT BLAST removes all mill scale and rust, cleans pipe to bare, bright metal, provides a slight "tooth" to hold coatings in positive bond. Priming coat is applied immediately after Roto Grit Blast.

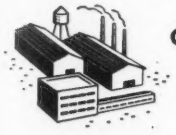


SECRET of Hill, Hubbell superiority is applying enamel in multiple 1/32" coats instead of one thick coat—pipe protection insurance that pays off in the field. Then pipe is tightly wrapped under even tension by special machines.



ELECTRONIC holiday detectors inspect every length of pipe before it leaves a Hill, Hubbell plant—further insurance that coatings have dielectric strength to resist electrochemical corrosion underground.

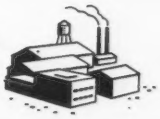
**THREE HILL, HUBBELL PLANTS TO SERVE YOU:**



**GIRARD, OHIO**
in the Youngstown Switching Zone

**LORAIN, OHIO**

**HAMMOND, IND.**
Chicago Switching Zone (in transit privileges)



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Pioneer in Pipe Protection for a Quarter Century

119a

structures and preparation of old structures for painting are discussed. Suitable aluminum alloys were suggested as alternate materials to mild steel in the exhaust boxes and retorts.—INCO.

8.4.3

**How to Combat Corrosion in Processing Oil and Gas.** MARSHALL E. PARKER. *Oil Gas J.*, **50**, 235-244 (1952) Mar. 17.

Briefly discusses each of the basic and special types of corrosion and presents a sketched illustration. Also includes detailed information on the following: losses caused by corrosion; weapons against corrosion; corrodents in the refinery; detection and diagnosis of corrosion; designing against corrosion; corrosion-testing methods; and controlling unanticipated corrosion.—BTR.

## 8.4 Group 4

8.4.3, 4.4.8

**Corrosion in Monoethanolamine Solutions.** M. E. PARKER. *Oil Gas J.*, **50**, No. 47, 122 (1952) March 31.

The development of the amine process for the removal of the acid gases from natural and refinery gas, together with the later combination amine-glycol process for the simultaneous removal of water has brought a set of corrosion problems. The acid gases carbon dioxide and hydrogen sulfide are the major corrodents in amine systems. The critical factor in glycol-amine system is the decreasing alkalinity of the amine with increasing temperature. Three things to lessen the rate of attack are reducing the operating temperature, removal of oxygen and organic acids, and substitution of more resistant materials. For aqueous amine where the attack is likely to invoke some galvanic action and where the critical location is the reboiler, types 304 and 316 stainless steel, Monel, Inconel, and Carpenter 20 steel are used. In glycol-amine systems the heat exchanger tubes are most rapidly attacked. Al 3S alloy, Al 3S Alcad, and 4-6 chromium, ½ molybdenum steel are satisfactory materials for tubes in this service.—INCO.

8.4.3, 6.1

**The Service of Metals in the Petroleum Industry.** (In French.) B. HEDDE D'ENTREMONT, *Metallurgie*, **83**, 271, 273, 275-276 (1951) Apr.

Various aspects, in particular the prevention of metal corrosion occurring in parts used in contact with petroleum fuels.—MR.

## 8.5 Group 5

8.5.3, 7.6.4, 5.8.1, 5.7.1

**Corrosion Control in Boiler Plants of Pulp and Paper Mills.** G. R. CONNOR, R. T. HANLON. Alchem Ltd. *Pulp and Paper Magazine of Canada*, **53**, No. 2, 65-70 (1952) Feb.

Carbon dioxide and hydrogen are the cause of corrosion of condensate return systems. A discussion of ion-exchange methods of treating water includes: The Sodium Cycle Cation Exchange System which removes calcium, magnesium and iron from the boiler feed, the Acid-sodium Cycle Exchange System in which carbonaceous or resinous materials are the exchange mediums, the Acid-sodium Cycle Cation Exchanger with caustic alkalinity correction, two stage deionization and hot Lime-Aluminate-Hot Zeolite Process. Amines, filming amines, catalyzed sodium sulphite are chemical treatments for prevention of corrosion in pipe-lines of condensate return systems. The selection of treatment system is discussed and conclusions are given. 8 references, 5 diagrams.—INCO.

## 8.6 Group 6

8.6.3, 6.4.4

**Magnesium Alloys in the Textile Industry.** F. EASTWOOD AND F. GREEN. *Metal Ind.* (England.) **79**, No. 6, 103-105 (1951) Aug. 10.

The textile industry is making extensive use of magnesium in their equipment. Warp beam flanges, previously composed of solid wooden barrels and malleable iron flanges, are now produced from magnesium sand castings or gravity di-castings. Three types of flanges are made, depending on the type of barrel used. Absolute rigidity of the flange is necessary, particularly in the sections of the industry which handle the synthetic yarns. Such yarns are more elastic than natural fibres and exert a tremendous pressure on barrel and flange. Nylon, by outward pressure, has been known to break ¼ inch thick cast iron flanges, and has crushed and twisted solid hardwood barrels. Warper's beams and barrels are also made from magnesium. Barrels up to 5 inches outside diameter are made of high strength extruded tube with a wall thickness of 3/16 or ¼ inch. Magnesium bobbins of all sizes are used for spinning, twisting, doubling, winding, cabling, stretching, steaming and dyeing. The flanges of these are magnesium pressure die-castings. The slip roller for use on opening and scutching machines working on cotton and rayon is an extruded tube with an outside diameter of 2¾ inches, inside diameter of 1¼ inches and a length of up to 4 ft. Hank polishing rollers, needle bars, selvedge bobbins, and needle boards are all made of magnesium. No corrosion difficulties have been found in normal mill atmospheres. The unprotected metal tarnishes, but the oxide films formed retard further oxidation. Chromating and painting are recommended chiefly in order to protect the accessories against deterioration in the event of being stored unused for long periods in mill annexes.—ALL.

## 8.8 Group 8

8.8.1, 4.3.3, 3.5.7

**Ammonia at 1000 Atmospheres.** W. H. SHEARON, JR. AND H. L. THOMPSON. Miss. Chem. Corp. *Ind. & Eng. Chem.*, **44**, No. 2, 254-264 (1952) Feb.

The construction factors involved in the first farmer owned nitrogen fertilizer plant, the Miss. Chem. Corp. at Yazoo City, are described. There are two reformer furnaces for hydrogen production, each containing alloy steel tubes filled with a nickel-base catalyst on a diatomaceous earth carrier. Aluminum sheeting is used on all piping and vessels. This application of aluminum, useful for protection and appearance, is corrosion-resistant except in strongly alkaline atmosphere and needs no painting. Two converters used in synthesis are carbon steel cylinders. Gas outlet tubes from conversion vessels and piping to the pre-cooler are of 60 nickel, 12 chromium, and 2.5 tungsten alloy. Ammonia and water-oil separators are high pressure vessels each constructed from a single steel forging. Experience shows that carbon steel is satisfactory in Claude units. Hortonspheres used to store ammonia are made of carbon steel covered with two layers of cork, a layer of chicken wire, a coat of mastic and finally aluminum paint. 13 references, and illustrations.—INCO.

8.8.4, 6.4.2, 6.3.10

**Tannery Maintenance: Corrosion Resistance of Pipes, Etc.** G. W. DOUGLAS. *Austral. Leather Tr. Rev.*, **47**, 5 (1951); *J. Soc. Leather Trades' Chemists*, **35**, 350 (1951) Oct.

DTD 346 aluminum alloy is specially suitable for toggles. Cases are known of staining by Staybrite in drying plants. Staybrite is not as resistant to corrosion as Monel in vegetable tan liquors. Monel had resisted for three years solutions containing up to 7% sodium chloride +3% acid.—INCO.

## 8.9 Group 9

8.9.1, 3.7.1

**Stratospheric Flight and Metallurgy.** *Aeroplane*, **82**, 334-335 (1952) Mar. 21. (Based on lecture by P. L. Teed.)

Brief discussion of some special problems on the above, including wear of commutator parts and various effects on corrosion and mechanical properties. Unusual effects on miscellaneous ferrous and nonferrous metals are mentioned.—BTR.

8.9.3, 5.2.3, 4.5.3

**Graphite Ground Anodes Protect High-Pressure Gas Lines.** A. W. PEABODY. (Ebasco Serv. Inc.) *Oil Gas J.*, **50**, No. 38, 374-489 (1952) Jan. 28.

Cathodic protection was found to be the best way to extend the pipeline life and prevent increases in gas loss through corrosion leaks by the Rochester Gas & Electric Corp. A soil survey was made and the procedure for the investigation of the corrosion is discussed.—INCO.

8.9.3, 5.4.3, 5.7.4, 5.8.1, 3.6.6

**Crude Lines, Products Lines, Tankers.** M. E. PARKER. *Oil Gas J.*, **50**, No. 5, 117 (1952) April 28.

The difficulty in Pipe-Line companies is on the gathering systems, where the use of cement-lined pipe was tried. Another type of interior coating being used is a plastic resin which is applied in place. Experience indicated that corrosion rates and total corrosion are most severe at the point where the gasoline is originally introduced into the pipe line. Finished products line corrosion and tanker corrosion (interior) are discussed. Also considered are dehumidification, inhibitors, and galvanic protection.—INCO.

8.9.4, 3.7.2

**Counters Tunnel Problem With Long Rails, Rubber Pads.** *Ry. Eng. & Maintenance*, **48**, 394-395 (1952) April.

Tells how Central of Georgia tries out new butt-welded rails with rubber pads placed above and below the tie plates in two tunnels in an effort to lick the problem of corrosion and excessive mechanical wear of ties.—BTR.

8.9.5, 5.11

**C. & E. I. Hopper Cars Are Designed for Exceptional Strength.** H. M. PRIEST. U. S. Steel Corp. Paper before R. R. Corrosion Conf., sponsored by INCO, Wrightsville Beach, May 1-3, 1951. *Railway Age*, **132**, No. 13, 38-41 (1952) Mar. 31.

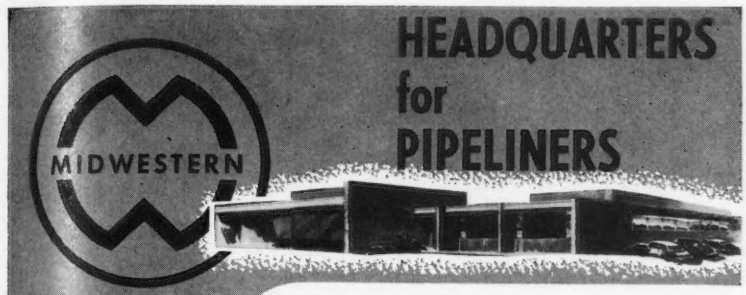
Pressed steel was used to build 1,000 cars of 70 and 50 tons capacities with slightly heavier sheets in contact with the load to reduce repairs and assure longer service life. When copper bearing steel is used, the plate thickness is increased 1/16 in. in the interior which is subject to corrosion from the coal loading. All steel plates, sheets and strips are open-hearth steel with a minimum 0.20 copper content, all other steel conforming to Association of American Railroads. Specification M-116-49. Illustrations.—INCO.

## 8.10 Group 10

8.10.2

**Production of Steel by the Oxygen-Impingement Process.** TH. E. SUESS. Part Translation of a section from the Yearbook of United Austrian Iron & Steel Works (Voest). *Iron & Steel Engr.*, **29**, No. 3, 91-93 (1952) Mar.

Impingement-blowing down on a bath of iron in a converter-like vessel permits working with higher temperatures than for instance, injection of oxygen through tuyeres in the bottom. The highest temperatures arise at the place where the oxygen jet impinges upon the surface of the liquid iron. Steel produced in this manner exceeds open-hearth steel in many essential properties. Pig iron can be so refined with oxygen that the blown steel needs no deoxidizing additions. This fact characterizes the peculiarity of the new refining method. Patent applications have been made on the process. Tables are given.—INCO.


CORROGLAS — A thin, flexible, inorganic glass wrap longitudinally reinforced for maximum wrapping strength. Corrosion protection in rolls from 400 to 1600 feet.

OUTER WRAP — An all-glass outer wrap with less than 1% water absorption rate. High porosity reduces holidays. Perfect for use in double-coat-double-wrap operations.

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8.10.3, 5.11

**Report on Corrosion Problems at the State Alluvial Diamond Diggings, Alexander Bay.** W. J. COPENHAGEN (Div. Chem. Services) and L. WHITBY (Paint Industries' Res. Inst.). South Africa, Div. Chem. Services, July, 1951, 10 pp.

Survey of structural metal work, fencing, stores and equipment showed considerable corrosion on ferrous parts. The main causes of such attack were considered to be: excessive humidity and erosion of paint coatings by sand, which contains aggressive salts. Mining machinery and excavators in the open are subjected to sand erosion and the effect of necessary downgrading in material specifications because metals such as steel, copper, aluminum, nickel (stainless steels) may be difficult to obtain in 1952, suggestion of alteration of environment and corrosion consideration at design level.—INCO.

structures and preparation of old structures for painting are discussed. Suitable aluminum alloys were suggested as alternate materials to mild steel in the exhaust boxes and retorts.—INCO.

8.4.3
**How to Combat Corrosion in Processing Oil and Gas.** MARSHALL E. PARKER. *Oil Gas J.*, **50**, 235-244 (1952) Mar. 17.

Briefly discusses each of the basic and special types of corrosion and presents a sketched illustration. Also includes detailed information on the following: losses caused by corrosion; weapons against corrosion; corrodents in the refinery; detection and diagnosis of corrosion; designing against corrosion; corrosion-testing methods; and controlling unanticipated corrosion.—BTR.

## 8.4 Group 4

8.4.3, 4.4.8
**Corrosion in Monoethanolamine Solutions.** M. E. PARKER. *Oil Gas J.*, **50**, No. 47, 122 (1952) March 31.

The development of the amine process for the removal of the acid gases from natural and refinery gas, together with the later combination amine-glycol process for the simultaneous removal of water has brought a set of corrosion problems. The acid gases carbon dioxide and hydrogen sulfide are the major corrodents in amine systems. The critical factor in glycol-amine system is the decreasing alkalinity of the amine with increasing temperature. Three things to lessen the rate of attack are reducing the operating temperature, removal of oxygen and organic acids, and substitution of more resistant materials. For aqueous amine where the attack is likely to invoke some galvanic action and where the critical location is the reboiler, types 304 and 316 stainless steel, Monel, Inconel, and Carpenter 20 steel are used. In glycol-amine systems the heat exchanger tubes are most rapidly attacked. Al 3S alloy, Al 3S Alcad, and 4-6 chromium, ½ molybdenum steel are satisfactory materials for tubes in this service.—INCO.

8.4.3, 6.1
**The Service of Metals in the Petroleum Industry.** (In French.) B. HEDDE D'ENTREMONT, *Metallurgie*, **83**, 271, 273, 275-276 (1951) Apr.

Various aspects, in particular the prevention of metal corrosion occurring in parts used in contact with petroleum fuels.—MR.

## 8.5 Group 5

8.5.3, 7.6.4, 5.8.1, 5.7.1
**Corrosion Control in Boiler Plants of Pulp and Paper Mills.** G. R. CONNOR, R. T. HANLON. Alchem Ltd. *Pulp and Paper Magazine of Canada*, **53**, No. 2, 65-70 (1952) Feb.

Carbon dioxide and hydrogen are the cause of corrosion of condensate return systems. A discussion of ion-exchange methods of treating water includes: The Sodium Cycle Cation Exchange System which removes calcium, magnesium and iron from the boiler feed, the Acid-sodium Cycle Exchange System in which carbonaceous or resinous materials are the exchange mediums, the Acid-sodium Cycle Cation Exchanger with caustic alkalinity correction, two stage deionization and hot Lime-Aluminate-Hot Zeolite Process. Amines, filming amines, catalyzed sodium sulphite are chemical treatments for prevention of corrosion in pipe-lines of condensate return systems. The selection of treatment system is discussed and conclusions are given. 8 references, 5 diagrams.—INCO.

## 8.6 Group 6

8.6.3, 6.4.4
**Magnesium Alloys in the Textile Industry.** F. EASTWOOD AND F. GREEN. *Metal Ind.* (England.) **79**, No. 6, 103-105 (1951) Aug. 10.

The textile industry is making extensive use of magnesium in their equipment. Warp beam flanges, previously composed of solid wooden barrels and malleable iron flanges, are now produced from magnesium sand castings or gravity di-castings. Three types of flanges are made, depending on the type of barrel used. Absolute rigidity of the flange is necessary, particularly in the sections of the industry which handle the synthetic yarns. Such yarns are more elastic than natural fibres and exert a tremendous pressure on barrel and flange. Nylon, by outward pressure, has been known to break ¼ inch thick cast iron flanges, and has crushed and twisted solid hardwood barrels. Warper's beams and barrels are also made from magnesium. Barrels up to 5 inches outside diameter are made of high strength extruded tube with a wall thickness of 3/16 or ¾ inch. Magnesium bobbins of all sizes are used for spinning, twisting, doubling, winding, cabling, stretching, steaming and dyeing. The flanges of these are magnesium pressure die-castings. The slip roller for use on opening and scutching machines working on cotton and rayon is an extruded tube with an outside diameter of 2¾ inches, inside diameter of 1¼ inches and a length of up to 4 ft. Hank polishing rollers, needle bars, selvedge bobbins, and needle boards are all made of magnesium. No corrosion difficulties have been found in normal mill atmospheres. The unprotected metal tarnishes, but the oxide films formed retard further oxidation. Chromating and painting are recommended chiefly in order to protect the accessories against deterioration in the event of being stored unused for long periods in mill annexes.—ALL.

## 8.8 Group 8

8.8.1, 4.3.3, 3.5.7
**Ammonia at 1000 Atmospheres.** W. H. SHEARON, JR. AND H. L. THOMPSON. Miss. Chem. Corp. *Ind. & Eng. Chem.*, **44**, No. 2, 254-264 (1952) Feb.

The construction factors involved in the first farmer owned nitrogen fertilizer plant, the Miss. Chem. Corp. at Yazoo City, are described. There are two reformer furnaces for hydrogen production, each containing alloy steel tubes filled with a nickel-base catalyst on a diatomaceous earth carrier. Aluminum sheeting is used on all piping and vessels. This application of aluminum, useful for protection and appearance, is corrosion-resistant except in strongly alkaline atmosphere and needs no painting. Two converters used in synthesis are carbon steel cylinders. Gas outlet tubes from conversion vessels and piping to the pre-cooler are of 60 nickel, 12 chromium, and 2.5 tungsten alloy. Ammonia and water-oil separators are high pressure vessels each constructed from a single steel forging. Experience shows that carbon steel is satisfactory in Claude units. Hortonspheres used to store ammonia are made of carbon steel covered with two layers of cork, a layer of chicken wire, a coat of mastic and finally aluminum paint. 13 references, and illustrations.—INCO.

8.8.4, 6.4.2, 6.3.10
**Tannery Maintenance: Corrosion Resistance of Pipes, Etc.** G. W. DOUGLAS. *Austral. Leather Tr. Rev.*, **47**, 5 (1951); *J. Soc. Leather Trades' Chemists*, **35**, 350 (1951) Oct.

DTD 346 aluminum alloy is specially suitable for toggles. Cases are known of staining by Staybrite in drying plants. Staybrite is not as resistant to corrosion as Monel in vegetable tan liquors. Monel had resisted for three years solutions containing up to 7% sodium chloride +3% acid.—INCO.

## 8.9 Group 9

8.9.1, 3.7.1
**Stratospheric Flight and Metallurgy.** *Aeroplane*, **82**, 334-335 (1952) Mar. 21. (Based on lecture by P. L. Teed.)

Brief discussion of some special problems on the above, including wear of commutator parts and various effects on corrosion and mechanical properties. Unusual effects on miscellaneous ferrous and nonferrous metals are mentioned.—BTR.

8.9.3, 5.2.3, 4.5.3
**Graphite Ground Anodes Protect High-Pressure Gas Lines.** A. W. PEABODY. (Ebasco Serv. Inc.) *Oil Gas J.*, **50**, No. 38, 374-489 (1952) Jan. 28.

Cathodic protection was found to be the best way to extend the pipeline life and prevent increases in gas loss through corrosion leaks by the Rochester Gas & Electric Corp. A soil survey was made and the procedure for the investigation of the corrosion is discussed.—INCO.

8.9.3, 5.4.3, 5.7.4, 5.8.1, 3.6.6
**Crude Lines, Products Lines, Tankers.** M. E. PARKER. *Oil Gas J.*, **50**, No. 5, 117 (1952) April 28.

The difficulty in Pipe-Line companies is on the gathering systems, where the use of cement-lined pipe was tried. Another type of interior coating being used is a plastic resin which is applied in place. Experience indicated that corrosion rates and total corrosion are most severe at the point where the gasoline is originally introduced into the pipe line. Finished products line corrosion and tanker corrosion (interior) are discussed. Also considered are dehumidification, inhibitors, and galvanic protection.—INCO.

8.9.4, 3.7.2
**Counters Tunnel Problem With Long Rails, Rubber Pads.** *Ry. Eng. & Maintenance*, **48**, 394-395 (1952) April.

Tells how Central of Georgia tries out new butt-welded rails with rubber pads placed above and below the tie plates in two tunnels in an effort to lick the problem of corrosion and excessive mechanical wear of ties.—BTR.

8.9.5, 5.11
**C. & E. I. Hopper Cars Are Designed for Exceptional Strength.** H. M. PRIEST. U. S. Steel Corp. Paper before R. R. Corrosion Conf., sponsored by INCO, Wrightsville Beach, May 1-3, 1951. *Railway Age*, **132**, No. 13, 38-41 (1952) Mar. 31.

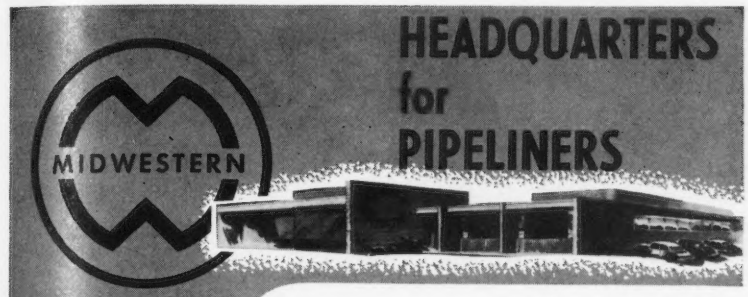
Pressed steel was used to build 1,000 cars of 70 and 50 tons capacities with slightly heavier sheets in contact with the load to reduce repairs and assure longer service life. When copper bearing steel is used, the plate thickness is increased 1/16 in. in the interior which is subject to corrosion from the coal loading. All steel plates, sheets and strips are open-hearth steel with a minimum 0.20 copper content, all other steel conforming to Association of American Railroads. Specification M-116-49. Illustrations.—INCO.

## 8.10 Group 10

8.10.2

**Production of Steel by the Oxygen-Impingement Process.** TH. E. SUESS. Part Translation of a section from the Yearbook of United Austrian Iron & Steel Works (Voest). *Iron & Steel Engr.*, **29**, No. 3, 91-93 (1952) Mar.

Impingement-blowing down on a bath of iron in a converter-like vessel permits working with higher temperatures than for instance, injection of oxygen through tuyeres in the bottom. The highest temperatures arise at the place where the oxygen jet impinges upon the surface of the liquid iron. Steel produced in this manner exceeds open-hearth steel in many essential properties. Pig iron can be so refined with oxygen that the blown steel needs no deoxidizing additions. This fact characterizes the peculiarity of the new refining method. Patent applications have been made on the process. Tables are given.—INCO.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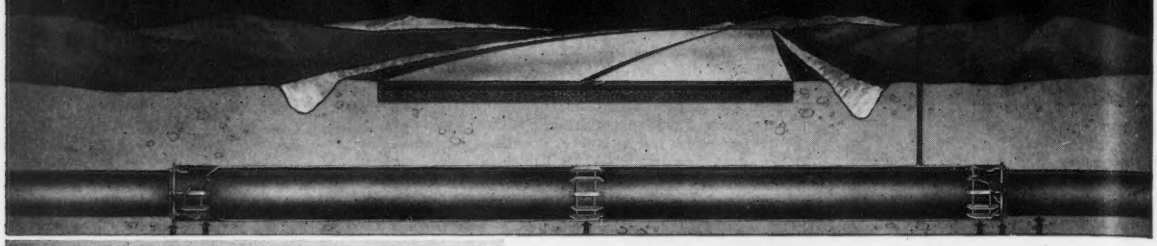

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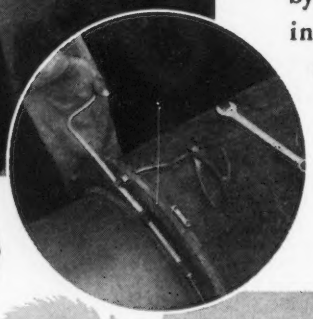

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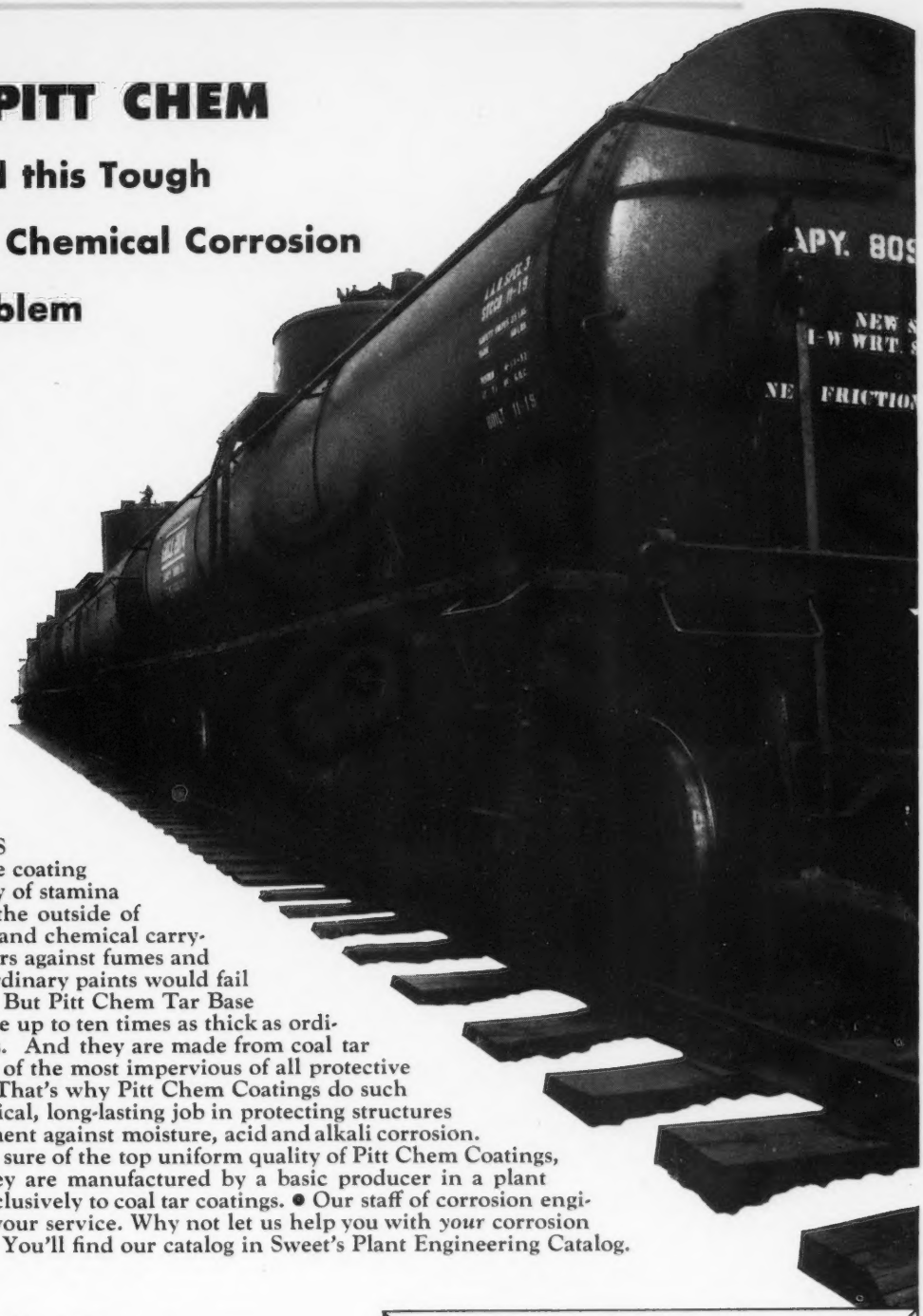


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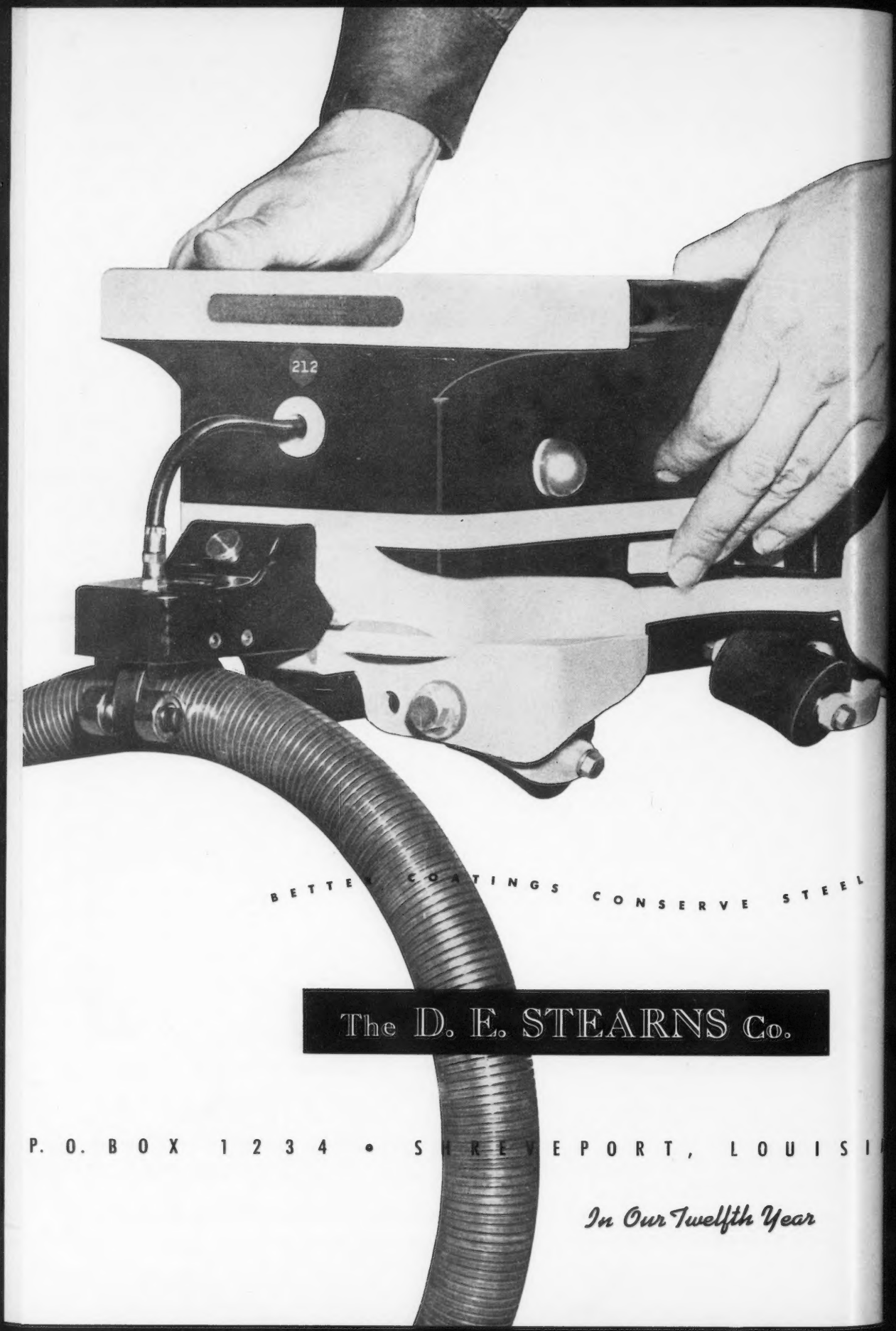


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